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Art. IX.—*The Physiography of the Werribee River Area.*

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[Read 11th July, 1918].

(With Plates XI. and XII., and 40 text figures).

I.—Area dealt with.

The area dealt with in this paper is that part of Victoria drained by the River Werribee and its tributaries. The country that has been visited and examined includes also the water sheds separating the Werribee from its neighbour rivers on the north, east, and west, and it was found convenient, for the following out of certain features, to further carry the investigations southward to include the You Yangs and Anakies, and the eastern face of the Brisbane ranges. This embraces a total area of nearly 1500 square miles, and is set out on the map shown as Plate XI.

II.—General Considerations.

While the Werribee is one of the smaller rivers of the State, it is in many ways one of the most interesting. The great stretch of plain about the Lower Werribee was the scene of many of the incidents of the early dawn of Victorian history. These great plains, known as "Iramoo," by the aboriginals, were crossed by Flinders (1802), Grimes (1803), Hume and Hovell (1824), and here also some of the first extensive land surveys were carried out by John H. Wedge, the first surveyor of the State.

In contrast with these early-known volcanic plains, now comparatively well settled, and crossed by important roads and railways, we have in the northern parts a large unmapped area, an area of steep, thickly-timbered ranges, intersected by a maze of gullies, an area where roads and fences are rarely seen, and where the sole inhabitants are occasional prospectors or sawmillers. These unsettled uplands, consisting of steep, quartz-strewn ranges, form portion of the great general uplifted and dissected peneplain of Victoria. Discussion is entered into as to the probable period when this planation was accomplished, and its relation to other tertiary features—the faulting and the volcanic periods.

Midway in the area is the green oasis of Bacchus Marsh, with its neighbouring complex geological formations, and its puzzling physiographic features; while an added interest to the whole area lies in the fact that several well-defined faults traverse the country and greatly influence the topography. The existence of certain of these faults will be demonstrated in this paper, and their great importance in the history and economy of the Werribee area, as well as their probable relationship to the general physiography of the State, will be dealt with.

The main part of the paper is of course occupied by a detailed description of each river, hill, and plain, as observed in the field. The structure and origin of each feature is considered. The "buried rivers" also provide material for a separate section, and the pre-basaltic drainage system has been partly reconstructed. The progressive physiography is then summed up in a "chronological column."

Research into the origin of the name of the river has revealed so much of interest in its varying nomenclature that it has been thought advisable to include mention of same, and this in turn involves some considerations as to early history and settlement. Finally, an effort has been made to correlate the present occupation of this area by man with the structural features and formations. In this section the various towns and villages in the Werribee area are considered in relation to their geographical situation. The influence of the main topographical features on roads, railways, water supply, etc., is also discussed.

III.—Previous Literature, Acknowledgements, etc.

While there has been little previous work done on the actual physiography of the Werribee or any part thereof, an enormous amount of material, geological and otherwise, has been published which has various bearings on same, and this has been utilised to the fullest extent possible.

(a.) Professor Skeats' University Geological Survey Party, 1915, which worked in connection with the Mines Department, devoted its time to the Blackwood parish, and especially to the neighbourhood of Greendale, in this area. The writer contributed a small paper on the physiography of the same, embracing the opinions of the party on the important "Greendale fault"; this has not been published, and has been, with the permission of Professor Skeats, largely embodied in this paper.

(b). The Lands Department courteously supplied copies of the numerous parish and county plans of the area, and these were

likewise utilized. The almost total absence of "features" from the parish plans greatly minimizes their value, and for part of the area dealt with, not even parish plans were available. Parts of the plan of County Bourke, for instance, remain to-day as they were first published, unfinished, many years ago, on the 1845-46 surveys.

(c). The geological formations underlying the surface features have necessarily been of prime importance, and the Quarter Sheets published by the Victorian Geological Survey have been liberally availed of. In addition, the writer has been kindly supplied by the Survey authorities with copies of the unpublished plans of Moorabool W., Moorabool E., Korweinguboora, Blackwood, Gorong and Darriwill. Further, he has been allowed to make tracings of unpublished quarter sheets 11 S.E. and S.W. The various reports of that department, including boring records, have also been utilized,

For all this, thanks are due to the Director, Mr. H. Herman, and his officers, especially Mr. W. Baragwanath, of the Ballarat Branch.

(d). The Military Survey of the Commonwealth has, fortunately, done a great deal of contouring work in this area. The writer has thus had the invaluable assistance of their published sheets, as well as access to all the original field notes of the surveyors, in which matter every assistance was kindly afforded by the officers of that branch; special thanks are due to the chief draughtsman, Lieut. Raisbeck.

Subsequent to the preparation of the paper, the Commonwealth Military Survey have published a contoured plan of the greater part of this area, on a scale of two miles to the inch. It is on sale as the Ballan-Meredith-Sunbury-Melbourne sheet, and reference to same would help to make clear many points in this paper that it was not possible to illustrate.

(e). The Railway Department has, during earlier years, accumulated much valuable information in the nature of trial railway surveys over various less-known parts of the area, and the writer was allowed to examine and make full notes from all these old surveys in their offices.

(f). In the matter of rainfall and water conservation, the Commonwealth Meteorologist and the State Rivers and Water Supply Commission courteously complied with all requests for information made to them.

(g). Since this account of previous literature has developed into a series of grateful acknowledgments, the writer would here wish also to place on record his chief acknowledgment—to Professor Skeats, of the Melbourne University, who first suggested this river as a subject of study, and who has also afforded every encouragement, and helped to make available many of the sources of information mentioned above.

(h). To Mr. A. W. Steane, of Ballarat, thanks must also be recorded. Mr. Steane accompanied the writer on his wanderings for many weeks during vacations, and assisted to explore numerous hills and valleys in which his interest was not great, and provided also an easy and rapid means of travelling from place to place.

A full list of the references quoted in this paper will be found at the end. (Section XII).

IV.—History, Early Settlement, Nomenclature, etc.

From the point of view of settlement, the two portions of the Werribee basin—the extreme upper and the extreme lower parts—present a marked and interesting contrast. The wide, level basalt plains of the Lower Werribee were among the earliest settled portions of the State, while the thickly-timbered, deeply-gullied, quartz-strewn Ordovician ranges of the upper Werribee still remain to a large extent uncharted and unsurveyed.

To go right back to the early morning time of the history of Victoria, we find that on Saturday, May 1st, of the year 1802, Matthew Flinders landed on the low Western shore of Port Phillip, and walked across these plains to the highest peak of the You Yangs, which he called Station Peak; from there he observed the plains of the Lower Werribee—the first white man so to do. His log-book entry is of some physiographic interest: "Our way was over a low plain where the water appeared frequently to lodge; it was covered with small-bladed grass, but the soil was clayey and shallow." (ref. 59). It was just two years later that a second explorer traversed these plains, in the person of Mr. Charles Grimes, then Surveyor-General of New South Wales. Grimes was sent by Governor King in 1803 to walk round and survey the harbour of Port Phillip. During this survey, on Monday, 14th February, 1803, he made the first crossing of what is now the Werribee River. Beyond mentioning the crossing, he leaves us no observation of any value (ref. 58).

In 1824-5, Hume and Hovell, in their overland journey from Sydney, also crossed the river, and it would appear that they gave the stream a name. Bonwick records in his book of 1883 (ref. 58, p. 83): "Piercing the Dividing Range near Kilmore they reached the Plains, crossed the Arndell, now the Werribee, and camped at what the natives called Geelong." Labilliere (ref. 59, p. 196) says: "Hume speaks of a stream he calls the Tweed. . . . The Tweed was probably the Werribee or perhaps the Saltwater River."

Having now mentioned two possible original names of the Werribee River, we find ourselves in the midst of a most confused period, during which no less than seven names were applied to that river whose name is now so firmly established as the Werribee. While briefly following out this matter, we may also endeavour to arrive at the origin of the present name.

We pass on to the period about 1835-6, when settlement of the Port Phillip District really commenced. Then came John H. Wedge, the pioneer surveyor of Port Phillip; to this gentleman we owe most that we know of the early settlement of the lower Werribee. He crossed the river, then in flood, on Sunday, August 30th, 1835 (ref. 58), and records: "This river I have named the Peel." (This was on the day that Fawkner's party landed on the site of Melbourne.)

Just about this time, also, the name of the River Exe was given to the Werribee, while Hume and Hovell's "Arndell" had become "Ardnell," and had been transferred to the more northerly stream (later the Saltwater). Bonwick (ref. 58, p. 275) refers to a map published by Arrowsmith, in 1837, giving "a river flowing south to Hobson's Bay, as the Ardnell, now the Saltwater." He adds: "Across the Exe and the Ardnell are written the words: Extensive and beautiful downs, called Iramoo by the natives."

Major Mitchell, viewing the Bay from the top of Mount Macedon, on September 30th, 1836 (ref. 60), says: "I perceived distinctly the course of the Exe and Arundell Rivers." Mr. F. G. A. Barnard states, in a letter, that the Werribee is mentioned in Batman's account of his settlement of Port Phillip, and is called the Exe. Mr. Barnard also points out that this name is still perpetuated in the village of Exford, situated where the Toolam Toolern Creek enters the Werribee.

We have thus had our stream as the Peel, Tweed, Exe, and Arndell; from now on the names applied approximate more closely to the present one. In 1856, Bonwick (ref. 57) reproduced an old map (undated) from the surveys of Wedge and others. On this the Werribee is shown, but not named, while the Saltwater is given two names; near the mouth it is named the Saltwater River; while higher up it is labelled "River Wearily."

By the courtesy of Mr. Saxton, of the Lands Department, the writer has been shown an interesting original map of part of the Harbour of Port Phillip by D'Arcy, July, 1837. This shows only the mouth of the Werribee, but it is clearly labelled "*River Weariby.*"

In 1838, in a map by Asst. Surveyor Smythe, the name is very distinctly lettered, and twice spelt "Weariby." It is believed by some that this name is the "Wearily" of the Saltwater transferred, and with the italic "l" of a previous map mistaken for a "b." Probably, however, the error was in the map reproduced by Bonwick, with an "l" replacing a "b."

Wedge published a good deal of description and some pictures from 1836 onwards, referring to the river as the "Peel or Weiribie River," and later, foregoing the name (Peel), which he had originally given, he refers to it as simply the "Weiribie." We thus see that within the first twenty years after its discovery, the river had been referred to as the Peel, Arndell (Ardnell, Arundell), Tweed, Exe, Weariby (Wearibie, Weiribie), and Werribee.

The present incomplete survey of this country has been referred to, and it is of interest, to note that in "Ham's Map of 1847," of which Mr. Barnard has kindly lent a tracing, the general outline of the Werribee and its tributaries is almost as well set out as it is at the present time.

From at least as early as 1847, and probably since 1840, the river has been consistently referred to as the Werribee River, although in 1866 Wedge wrote a letter to Bonwick, in which he refers to the Weiribie River.

While Bonwick mentions the changes which have taken place in names, and quotes the Wearily becoming Werribee as an instance, there is still a possibility that the name is of aboriginal origin. For instance, Wedge, who was the first settler on the river, and a man of parts, would hardly forego the prior name of "Peel," given by himself, to such a chance-grown name as Weariby. Further, in one of his sketches he refers to the Weiribie Yaloak; and since the latter is the aboriginal word for river, it naturally suggests that the first word was also native. Mr. G. Firth Scott (ref. 61, p. 94), says with reference to Hume and Hovell's journey: "Arriving at a creek named by the blacks Werribee, and by Hume the Arndell, they refreshed themselves," etc. The writer believes for the above reasons, that the name was an aboriginal one. Whatever the mode of origin may have been, the rather euphonious title of "The Werribee," has now been firmly established.

There are many other interesting facts on record concerning the origin of place names in this area, but most of these are well known, as, for instance, the complex story of the naming of the You Yangs and the Anakies. While it is satisfactory to note the large percentage of aboriginal names preserved, some of these have locally fallen into disuse, although still recorded on the maps. For example, Wuid Kruirk, a dominating hill almost on the Divide, is known only by the name of Blue Mountain—a name too common to be of much value. Again, the Korjamumnip Creek is almost always referred to either as Doctor's or Pyke's Creek, while the Korkuperrimul in its lower part is called Lyell's Creek.

Four of the parallel northern tributaries of the Werribee are interesting in that their aboriginal-sounding names all commence in "Kor,"—i.e., Korweinguboora, Korjamumnip, Korobeit, and Korkuperrimul; this Mr. Saxton believes to be an imitative reference to the sound made by a frog, and used to denote water.

It is difficult to find any reliable translation of these or other aboriginal place names. The early settlers often mistook words of the blacks, and almost always finally came to mispronounce them. Then, on being written and introduced into maps, further changes of pronunciation would probably take place, and effectively disguise whatever original meaning the words may have had. Added to this there is a strong tendency among us, unfortunately, to anglicise the pronunciation of native names; and thus, for example, we find the pleasing name of Naracoorte (S.A.) pronounced and written "Narrowcourt."

Another peculiar feature is the giving of the same place name to two well separated places. Thus we have Steiglitz, a volcanic elevation on the open plains of Ballan, while the mining town of Steiglitz is in the heart of the heavily-timbered Brisbane ranges, about twenty-five miles away. Both places are named after an early settler (1838) von Steiglitz (ref. 62). More confusing and anomalous is the application of the name of "Mount Blackwood," long given to the volcano north-west of Bacchus Marsh, to the mining town seven miles away, in the *valley* of the Lerderderg River. There is very little communication between the two places, and their postal services come from quite different directions.

The Lerderderg River also presents a problem of nomenclature, It is believed by some to be aboriginal, and to signify a "broken reed." Others state that the name was given by Messrs. Bacchus and Hepburn, who, when exploring in these wilder parts, were constantly humming certain minstrel refrains, then "all the rage" in London. Thus, it is stated, we get the "Jim Crow," a creek near Daylesford, and the "La-di-dah"—from two of the better known refrains. This word La-di-dah, on being printed on maps, was given (it is said) the dignity of an improved spelling, which led to our present "Lerderderg."

The late Mr. C. Crisp, of Bacchus Marsh, a well-known authority on the history of that district, published a brief account of Bacchus Marsh in 1891; therein he mentions the Lerderderg as being the camping place of Mr. Bacchus, junr., in 1838, and states that the river was then called Lardedairk by the natives. This account of the origin of the name seems the most probable one.

It will be seen that the gathering of reliable accounts of the origin of place names is attended by much difficulty. An effort has been made in this section to bring together, as briefly as possible, the most interesting and most reliable instances. Kind assistance in the collection of historical facts was given by Mr. A. W. Greig, Secretary of the Historical Society of Victoria, and by Mr. Saxton, of the Lands Department.

V.—Rainfall and Water Supply.

It has been found possible under this head to make some attempt at quantitative work. By the courtesy of various officials, records of rainfall, evaporation, run-off, sediment carried, etc., have been collected.

It may be advanced as an apology that the records are few, and do not extend over a length of years. Still it is possible to make estimates from the material in hand, and this has been done. It will at any rate serve as a beginning with which future workers in this area may make comparisons.

(a) *Rainfall.*—This as supplied by the Commonwealth Meteorologist from sixteen selected stations, in or near the Werribee basin, is set out in tabular form as follows. The stations are placed in order from maximum to minimum. They are the records for the past ten years, and include the very wet year of 1911, with more than 12 in. over the average, as well as the dry years of 1908 and 1914.

RAINFALL IN THE WERRIBEE AREA—(10 YEARS, 1905–1914).

	Barkstead	Blackwood	Riddell's Creek	Bullengarook	Ballan	Bolinda	Gisborne	Sunbury	Myrniong	Bacchus Marsh	Keilor	Werribee	Little River	Mt. Rothwell	Mt. Cotterill	Melton	Yearly Average
1905 ...	...	38.40	22.82	24.15	24.26	...	...	23.62	22.51	22.26	22.69	21.51	17.39	20.66	...	18.79	... 23.25
1906 ...	...	48.26	30.70	...	28.98	...	..	23.22	23.88	21.97	20.36	19.11	16.32	17.45	...	18.78	... 24.46
1907 ...	...	33.01	...	...	21 14	...	22.47	19.03	16.96	18.75	17.76	16.78	17.60	17.48	16.97	17.43	... 19.61
1908 ...	...	26.65	...	16.33	16.61	15.69	20.10	13.36	12.49	12.92	12.78	13.58	...	13.31	11.16	11.52	... 15.11
1909 ...	46.61	46.57	29.88	28.20	26.74	...	29.58	22.32	25.20	21 23	20.60	20.93	21.19	22.37	18.21	...	... 27.11
1910 ...	39.41	39.67	26.86	28.74	24.97	26.49	27.23	22.61	22.31	21.65	20.34	20.53	19.63	17.89	19.13	16.20	... 24.60
1911 ...	47.04	50.04	40.54	39.38	37.84	36.79	...	37.04	32.78	29.23	28.52	26.48	27.05	26.13	27.20	...	... 34.71
1912 ...	...	31.39	21.81	20.64	23.47	22.11	...	21.00	17.48	15.78	18.24	16.08	15.53	13.83	14.65	10.60	... 18.82
1913 ...	...	37.54	26.49	...	31.37	24.91	...	22.68	19.39	18.25	17.86	17.35	15.19	14.77	15.94	15.56	... 21.33
1914 ...	23 72	22.62	19.92	...	16.56	...	...	20.09	15.55	14.60	16.03	12.82	11.25	12 36	13.56	13.54	... 16.35
Average	39.19	37.41	27.37	26.24	25.19	25.19	24.84	22.49	20.85	19.66	19.51	18.61	17.90	17.62	17.10	15.30	
Maximum	47.04	50.04	40.54	39.38	37.84	36.79	...	37.04	32.78	29.23	28.52	26.48	27.05	26.13	27.20	18.79	
Minimum	23.72	22.62	19.92	16.33	16.56	15.69	...	13.36	12.49	12.92	12.78	12.82	11.25	12.36	11.16	10.60	

This table shows in an interesting way how the various factors operating at any one locality remain uniform in their results throughout all years. As has been stated, the stations are arranged in order, from that with the greatest average fall for the ten years, to that with the lowest. The years of maximum and minimum rainfall show very nearly the same gradient.

The average rainfall for the Werribee and Saltwater valleys, published by Gregory, from figures supplied by Mr. Barrachi, is 27 in. (ref. 20).

The Werribee average, however, must be much lower than this, as the figures of the above table are those of a representative ten years, and give an average of 22.5 in. The Commonwealth Meteorologist, treating the area broadly, in his chart of Victorian rainfall, divides the area into zones practically parallel with the coast:—

(1) The mountain area with a rainfall 30 in.—40 in.; (2) an intermediate belt 20 in.—30 in.; and (3) a coastal belt with a rainfall of 10 in.—20 in.

This is not the whole truth, however, as certain local differences occur, and an endeavour is made to bring out these points by means of the diagram shown in Fig. 1.

Since there is an undoubted lowering of the rainfall from the Divide to the sea, the chief factors must be (1) height above the sea of the station selected, and (2) nearness to the main ranges. The two factors are closely parallel, but not quite so. Selecting these two factors, the diagram (Fig. 1) has been drawn thus:—(a) The sixteen stations are arranged at even intervals with vertical lines drawn to graphically represent the amount of rainfall; (b) In the same order, the stations are again similarly arranged, the vertical lines now representing, inversely, the nearness to the Main Divide, measured as distance from the river mouth; (c) in the third case the vertical lines represent the heights above sea level of the various stations. It was thought that, if these were the only factors, the curves joining the tops of the three sets of lines would closely resemble one another, and that any irregularity in the second curve should be compensated for in the third. This proves to be the case, with one or two interesting exceptions.

(a) It is clearly suggested by the diagram that the amount of rain received is closely proportionate to the nearness to the Main Divide. The rain-bearing winds travel across the area mainly from the west and north-west, proceeding from the higher to the lower portions with a gradually decreasing rainfall. The third column shows that three stations—Riddell's Creek, Bolinda Vale and Sunbury—stand at lower levels than their rainfall would suggest, but all three lie in valleys considerably lower than their immediate surroundings.

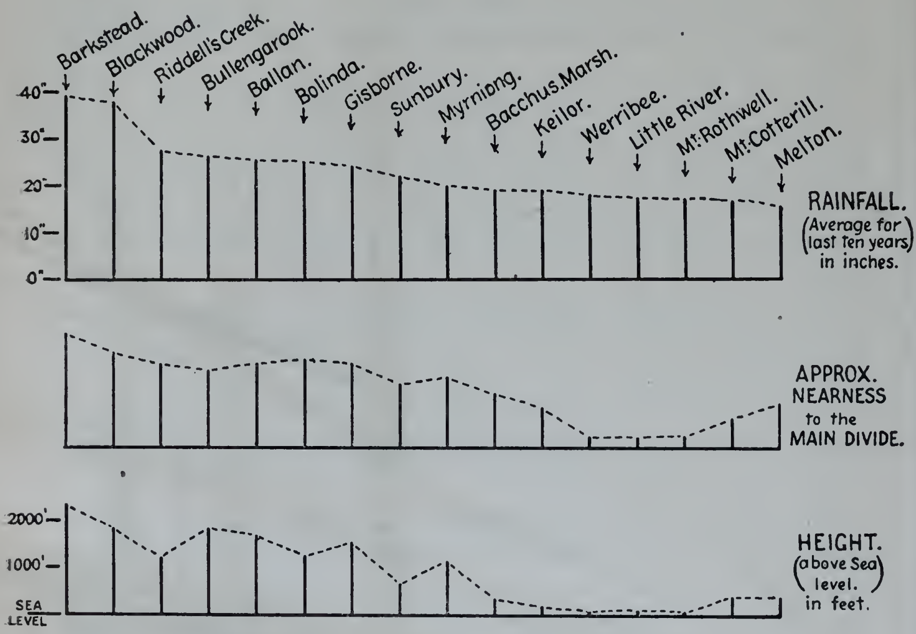


Fig. 1.—Diagram, showing comparison between the average rainfalls of various places in the area, with their heights above sea-level and distances from the sea.

The second irregularity shown is that of Melton and Mt. Cotterill, both of which have lower averages than would be expected. This may be due to the fact that the four preceding stations in the diagram—all nearer the coast—have their averages raised by coastal showers, which do not reach as far inland as Melton and Mt. Cotterill; while the western and north-western rain-bearing winds, which determine the rainfall of the area as a whole, have lost most of their moisture before reaching this belt.

(b) It may be, also, that these westerly and north-westerly winds, descending abruptly from the Ballarat plateau (average elevation over 1300 ft.) to the Lower Werribee plains (average elevation under 500 ft.), and thus suddenly becoming more compressed, and therefore warmer, are less ready to part with their remaining burden of moisture; this sudden change in level takes place along an almost north-south line, referred to in this paper as the Rowsley or Bacchus Marsh scarp.

An interesting and independent corroboration of this point is afforded by the observations of Mr. R. Dugdale, of Bacchus Marsh. Mr. Dugdale has a very extensive knowledge of the whole of the area, from the point of view of land values, and informs the writer that local land buyers have long recognised a "dry belt" passing from a little east of Anakie through Nerowie, Mt. Cotterill, and Melton, almost parallel to the coast. This is a matter of economic interest, and the explanation of this dry belt appears to be as stated above.

(b) *Evaporation.*—Mr. H. C. Wilson, Manager of the Government Research Farm, supplies the following records of evaporation from a free water surface, taken at that farm, near the town of Werribee:—

Year	Rainfall	Evaporation
1913	16.43 inches	46.43 inches
1914	13.24 ,,	50.54 ,,
1915	15.55 ,,	51.75 ,,

For the three summer months of the former two years, the average monthly evaporation was as much as 7.11 inches, while for the winter periods the average was 1.44 inches. During the same period the average daily amount of "bright sunlight" for the year was 5.2 hours. For the three winter months the daily average was 4.0 hours, and for the summer period 7.6 hours per day.

It will thus be seen that evaporation is probably an unusually predominant factor in the disposal of the rainfall in these wide volcanic plains of the lower Werribee. The soil is generally somewhat clayey, and except after a very dry period when the soil cracks are widely opened, the percolation would be small, similarly the drainage is poor, swamps are common, and the run-off would be comparatively low. With the dry conditions, and the level nature of these plains, irrigation is naturally suggested, and we find that two of the most important farms of the State (the Government Research Farm and the Metropolitan Board Farm) are situated here. Both these farms are on a large triangular patch of river-built material, the soil of which is largely basaltic in origin, although much more sandy and porous than if wholly basaltic.

(c) *Run-off, etc.*—It is probably in the steep, wooded ranges of the upper part of the basin that the maximum run-off occurs. The contributing factors there are (1) steepness of the valley sides, (2) fairly impervious nature of the rock, and (3) the higher average rainfall. Percolation is probably at a maximum where the sandstones of the permo-carboniferous period outcrop, as these are very porous. and much fractured and faulted. They provide good, but not permanent springs.

In the figures published by the State Rivers and Water Supply Commission (River Gaugings, 1905, p. 7, et. seq.), it is shown that peculiar anomalies exist with regard to the percentage of run-off of Victorian Rivers, and also that very great variations occur. From the table showing the maximum and minimum annual discharges for the whole period, covered by their gaugings, it appears that the average maximum discharge is 31.5% of the total rainfall, while the average minimum is 7.9%.

We may compare with these the following figures for the Werribee and its tributaries:—

Station	Year	Mean Annual Rainfall	Total Average discharge	Percentage of Total discharged
Pyke's Creek } -	1909 -	37 in. -	34,170 acre-ft. -	34%
near Ballan } -	1912 -	36 in. -	3,490 acre-ft. -	4%

This great variation in the amount of run-off must be due to the different distribution of the fall throughout the years mentioned. The Werribee River, at the mouth of the Gorge, shows similar variations, with an unusually high percentage discharge in 1909:—

Station	Year	Mean Annual Rainfall	Total Average discharge	Percentage of Total discharged
Werribee River } -	1909 -	30 in. -	73,970 acre-ft. -	40%
near the Gorge } -	1912 -	22 in. -	14,450 acre-ft. -	11%

The gaugings on the Lerderderg at Darley are incomplete, and do not show any evidence bearing on this matter. Those taken at the town of Werribee, not far from the mouth, should really approximate to the total annual run-off for the whole river basin. They are:—

Station	Year	Mean Annual Rainfall	Total Average discharge	Percentage of Total discharged
Werribee River } -	1911 -	34 in. -	179.920 acre-ft. -	19%
at Werribee } -	1912 -	19 in. -	36,990 acre-ft. -	7%

(d) *Water Storage.*—Since the figures in the last section are the only data available for the whole area, and since 1911 and 1912 were respectively very wet (34 in.), and very dry (19 in.), an approximation to the normal discharge might be taken from an average of the two, and would give us about 100,000 acre feet per annum.

As far as can be learnt, the following are the only tributes levied on the river at present:—

Pyke's Creek Reservoir: Capacity, 14,800 acre-feet.
Exford Reservoir: Capacity, 10,000 acre-feet.
Bacchus Marsh (Town): Domestic supply of town.
Werribee (Town): Domestic supply of town.

It is very evident that much more can be done in the way of water storage in this basin. Ballan, although situated on the Werribee, draws its supplies from a railway department reservoir on the upper Moorabool, a river also largely utilized by the Ballarat and Geelong Water Commissions. It seems remarkable that such a fine stream as the Lerderderg River—the dominant stream of the whole basin, and fed by excellent permanent springs in its upper branches, should so far not have been used for storage purposes. A small reservoir originally existed on the Lerderderg above the town of Blackwood, the water being wholly for mining purposes, but this dam was destroyed by a flood many years ago.

(e) *Sediment Carried.*—A series of tests of the amount of solids in suspension was made during seven representative months of 1890. (See River Gaugings, Vict., 1905 and 1912.) The results were:—

Date	Werribee River at Bacchus Marsh	Lerderderg River near Bacchus Marsh
December 8	.20 grains per gal.	1.18 grains per gal.
January 13	.63 ,, ,,	1.82 ,, ,,
February 10	.27 ,, ,,	1.85 ,, ,,
March 10	.36 ,, ,,	1.07 ,, ,,
April 13	.46 ,, ,,	.54 ,, ,,
May 12	1.83 ,, ,,	6.10 ,, ,,
June 15	2.65 ,, ,,	1.97 ,, ,,

These may fairly be taken to be the natural burden of the streams, uninfluenced by any mining operations. From a consideration of the figures, the writer has taken 2 grains per gallon as a fair average of the material carried in suspension. No account is taken of the material in solution. Applying this to a year for which the more complete data are available, the wet year of 1911, we get an estimate of about 6250 tons of solid carried to the sea in that year—an average of about 12 tons per square mile. Probably more complete data will show that this estimate is below the truth.

If we compare these figures with those of the great and actively-eroding rivers in other parts of the world (Russell, "River Development"), we find that the Werribee is not doing very extensive eroding work. This is indicated by the following figures, showing the proportion between the weight of sediment carried and the weight of water :—

Rio Grande, 1 : 291.
Uraguay, 1 : 10,000.
Werribee, 1 : 35,000.

The figures on which this result is based are reliable, but, unfortunately, incomplete. In view of the comparatively high grades of the various streams of the Werribee, and the extensive dissection proceeding in the uplifted blocks, clearly shown in Fig. 30, the result seems very low.

It must be remembered, however, that the rainfall is comparatively poor, and spread over the greater part of the year. Since a river does most of its erosive work in flood time, and especially at maximum floods, this distribution of the rainfall must be a factor against high erosion. Further, the river is working largely in very resistant rocks—indurated palaeozoic sediments and almost undecomposed basalts. Probably the above ratio would be more comparable to that of streams of the same size, working under similar conditions; no figures for such comparisons were obtainable by the writer.

VI.—Introductory Survey of the Area.

In order to convey a preliminary general idea of the physiographic features of the area, we may imagine that we are enabled to take a bird's-eye view of the whole country-side. (c.f. Plate XI.) The general impression would be of an area of low relief, rising from the flat shores of Port Phillip Bay to a general level of about 2400 feet at the "Main Divide" of Victoria, some 50 miles northward.

Colour differences, due to the contrast between the heavily-timbered and the pastoral areas, would be apparent, and the winding southern and south-easterly rivers would be visible. Along these, narrow deeply cut gorges would be noted, apparently irregular in their distribution. With these colour differences as a basis, and in order to deal with the area in greater detail, we may differentiate the whole into five main topographic "blocks." These are set out in Fig. 2, and are called A, B, C, D, and E. (See also block diagram Fig 3.)

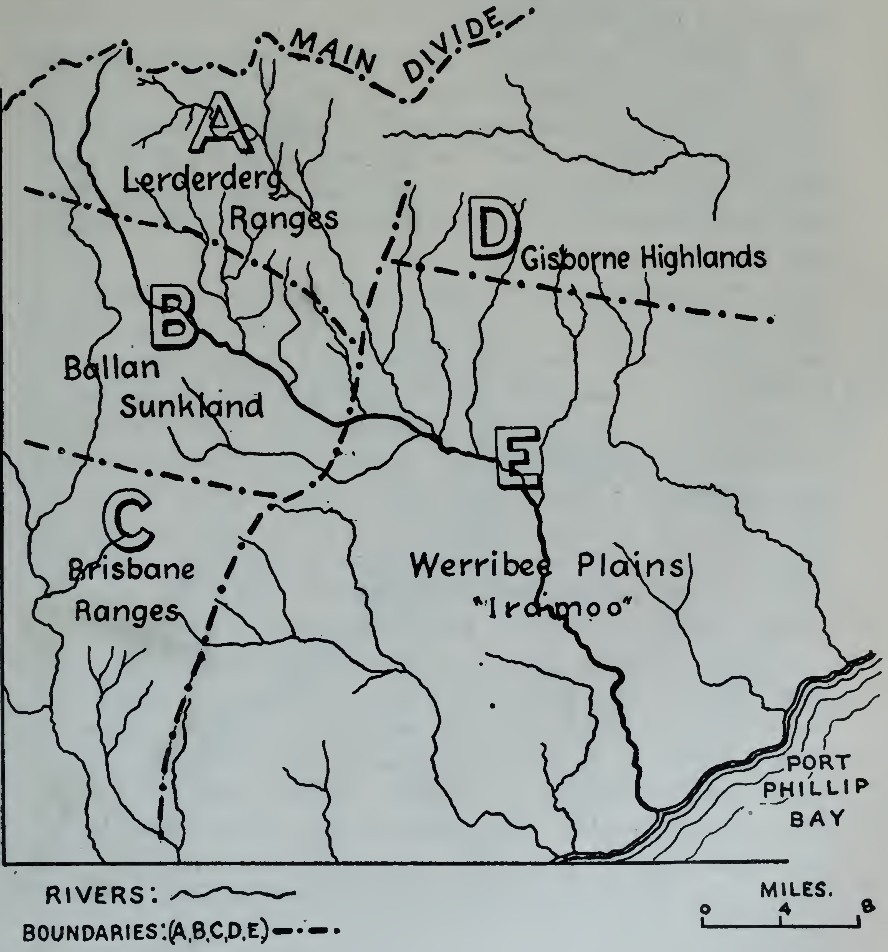


Fig. 2.—Subdivision of the area into five structural blocks for descriptive purposes (Section VI.).

(a). In the N.W. and S.W., blocks A and C stand out as great dark-coloured oblong masses of relatively high relief. Both are heavily timbered "Ordovician ranges," deeply scored into by river valleys, and they represent two separate portions of the great uplifted peneplain of Victoria.

On account of their numerous and steep valleys, both these areas present great difficulty for the building of roads or railways. In A the only occupations possible are those of gold miner and saw miller. In C this is also the case, except in the W. and S.W., where lava-flows and other features have so altered matters as to allow of grazing and agriculture with comparatively easy communication along N.S. lines.

(b). Block D, in the N.E., is also a relatively high mass, but lacks the unity of structure shown by both A and C. It is an elevated ordovician area, augmented in height by numerous volcanic hills and flows of lava. To the north of this is the Gisborne Creek valley, trending eastward, while the southern slopes contribute several streams (Pyrete, Djerriwarrh, Toolam Toolern Creeks, etc.) to the Werribee.

(c). The Central block, B, is the most interesting and complex of the five. It is an area of varied geological structure, as may be seen by reference to the geological map of Victoria. Not only so, but the rocks are such as to provide good soils, and the topography on the whole, allows for easy communications. While the surface of block A is wholly Ordovician, blocks C and D mainly Ordovician and Newer Volcanic, and block E almost wholly Newer Volcanic, this interesting area (block B), contains a very limited outcrop of lower Ordovician, abundant glacial sandstones, Older Volcanics, widespread fossiliferous Tertiaries, and broad sheets of Newer Volcanic. It is well settled, and mainly pastoral.

(d). The last block, E, constitutes the great level plains of the lower Werribee, almost wholly volcanic and lying at a considerably lower elevation than any of the other blocks. These plains are generally treeless, or sparsely timbered, and the land is everywhere occupied, mainly by graziers. In the south-west, at the mouth of the Werribee, is an important and closely settled irrigation area, while in the N.W., where the Werribee enters these plains, and where the important tributaries of the Korkuperrimul, Lerderderg, Parwan and Pyrete Creeks all meet together, is the somewhat remarkable and wonderfully fertile basin of Bacchus Marsh.

We should also note the great influence of the Newer Volcanic (late Tertiary) flows on Blocks B, D, and E. The old physiographic features of these areas were almost wholly blotted out by the lava flows, and a new set of streams has subsequently developed.

No single mountains stand out. The main divide is scarcely above the general level of the uplifted peneplain block on which it lies. Several important volcanic cones, however, rise above this general level, and gain their impressiveness from the elevations on which they stand. First in importance is the dominating cone of Mt. Blackwood (2432 feet), standing on the south-eastern edge of the lifted block A. Mounts Bullengarook (2207 feet), and Gisborne (2105 feet), stand likewise on the high ridge of Block D. The most important height near the Main Divide is also volcanic; it is called Wuid Kruirk (more popularly Blue Mountain, 2800 feet), and is practically on the Divide. Two large masses, the Anakies (1350 feet) and the You Yangs (1134 feet), are on the lowest block, E. The You Yangs is a fine monadnock of granite, which still rises high above the lava flows of the plain; while the Anakies are partly granite, accompanied and dominated by a chain of high volcanic cones.

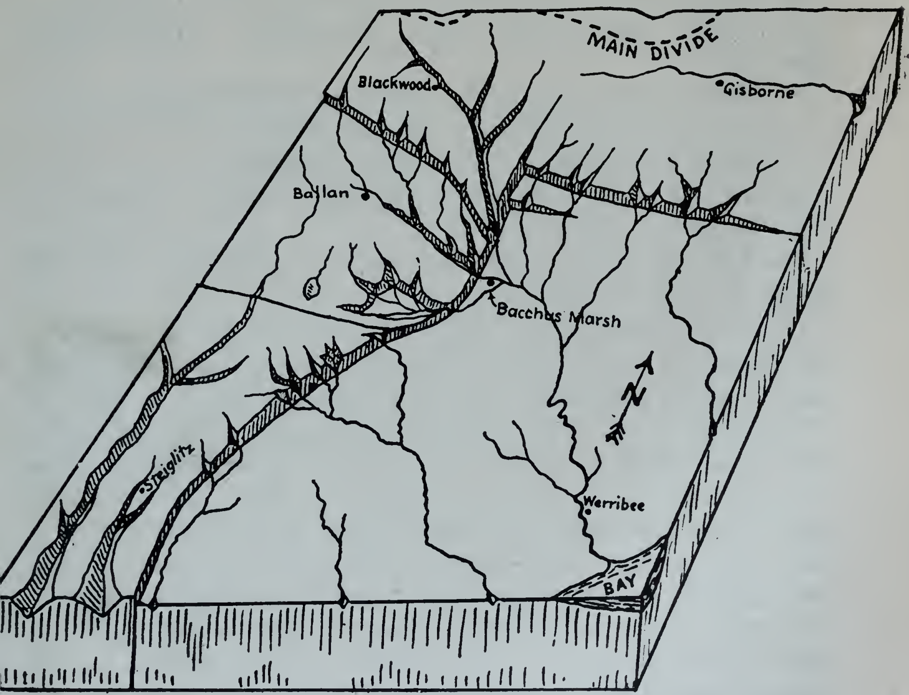


Fig. 3.—Block diagram of the area, looking from the south-east, to show relative positions of the main scarps and streams.

Fig. 3 has been drawn in order to give a rapid visual impression of these five great divisions and their relation to the Werribee and its tributaries. The figure is drawn as if viewed from the south-east.

The boundaries between these five divisions are not artificial, but natural. According to the belief of the writer, such boundaries are in all cases dominant fault lines. Detailed discussion of these important faults will be found in a later portion of the paper.

VII.—The Rocks of the Area.

Before entering upon the detailed account of hill and valley, we may with advantage discuss the nature of the various types of rock that occur, in so far as their nature and structure bear on the problems of physiography. For convenience we shall deal with the rocks in order of age :—

(a) Strongly folded sandstones, quartzites, and slates (Lower Ordovician).

(b) Granites and Granodiorites. (? Silurian and ? Devonian.)

(c) Glacial conglomerates and Sandstones. (Permo-carboniferous.)

(d) Older Basaltic lava flows. (Early to Middle Tertiary.)

(e) Gravels, sands and clays. (Middle Tertiary.)

(f) Newer Basaltic lava flows. (Later Tertiary.)

(g) Gravels, sands, soils, etc. (Post-Newer basaltic to Recent.)

(h) Dykes of various ages.

The following notes should be read in conjunction with the geological map of Victoria :—

(a) *Lower Ordovician.*—These rocks form, as far as is known, the bedrock of the whole area; they also outcrop over a very large part, forming practically the whole surface of Block A, most of C, and part of D. They consist of sandstones, quartzites, grits, and slates, intensely folded into anticlines and synclines; these strike almost due north, with variations of a few degrees east or west. They have been enormously eroded, since in the past they may have formed a land surface exposed to atmospheric erosion ever since the close of the far-away Lower Ordovician period.

In this connection, however, there are other possibilities that must not be overlooked. For instance, A. R. C. Selwyn, in his Notes on the Physical Geography, etc., of Victoria, 1866 (ref. 50, pp. 9, 10), draws attention to the possibility that the upper palaeozoic sediments of the Grampians area in the west, and the Mansfield-Mt. Wellington area in the east may once have extended in a "broken and undulating anticlinal arch," right across the intervening area. The accompanying diagram is but slightly altered from that published by Selwyn, and suggests the possibility referred to (see Fig. 4). Except the smaller outlier of the Cathedral Range, in the Acheron Valley, no traces of these upper palaeozoic rocks have yet been recognised between the Grampians and the Mansfield area. Possibly, therefore, this intervening area was in those times

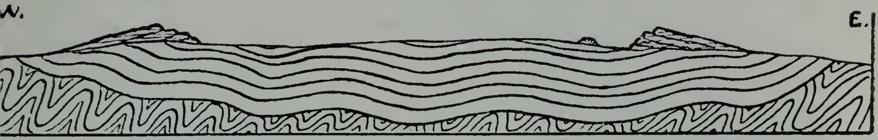


Fig. 4—Section to illustrate Selwyn's conception of the possible geological structure of Victoria as referred to in Section VIIa. This shows a geosyncline of Lower Palaeozoic rocks, with a broken anticlinal arch of Upper Palaeozoics. The underlying schists and gneisses have been added to those shown in Selwyn's diagram.

an elevated north-south area on the flanks of which these two widely-separated deposits may have been laid down in two distinct basins. The possibility that they once extended across the area under discussion is, however, worthy of consideration.

In the permo-carboniferous period vast sheets of glacial material were deposited on the Ordovician, and many remnants still remain; the protective effect of these beds must be borne in mind, but the glacial period itself is, in the foregoing paragraphs, regarded as an erosive period as far as the lower palaeozoic rocks are concerned, There does not appear to be any good reason for believing that the jurassic sediments of southern and south-western Victorian ever extended so far north as to affect the Werribee River area. Neither does it seem probable that the tertiary marine invasions ever extended over the present Ordovician uplands of the area dealt with in this paper.

Induration of these lower Ordovician rocks is in all cases so advanced that although, owing to the repeated folding, a variety of beds are exposed running in N.S. lines, little differential erosion is to be noted. In some cases in Block A (the Blackwood Ranges), north of Greendale wide quartzite bands may be followed along the ridges, in the formation of which they have no doubt played their part. Both E.W. and N.S. dykes occur; in places the former are very numerous.

Considerable faulting and jointing is noticeable and this has helped to give direction to various valleys. An interesting case is that of Back Creek, surveyed by the Melbourne University Survey Party in 1915. As shown in Fig 33, this stream is a fairly good example of a "drainage network" (ref. 32, p. 226). In places igneous intrusions have turned these beds into hornfels or spotted slates, as exemplified in the Werribee Gorge area, but such alteration is not considerable.

The present total thickness of these beds is unknown. In the Bendigo gold field similar rocks were penetrated to a depth of 4600 feet, and proved of the same character throughout. We may sum up this most important series of rocks as being extremely and almost uniformly resistant to erosion. (Throughout this paper the term "Ordovician" refers to these lower Ordovician beds.)

(b) *Granites and Granodiorites.*—The nature of the plutonic intrusive masses, regarding their resistance to erosion, is well known. Granite forms the great mass of the You Yangs, whose highest point (Station Peak) still rises like a pyramid 1154 feet above sea level, and over 800 feet above the basalt and alluvial surrounding it. Towards the Anakies this granite is much worn down, and remains as low hills capped by huge residual tors. The only granodiorite exposed is a small area in the Werribee River, between Bacchus Marsh and Ballan. It assists in forming the rugged and precipitous "Werribee Gorge." On the surface it proves no more resistant than the rock (Ordovician), which it intrudes, and presents a fairly level surface of somewhat clayey and gritty soil.

(c) *Permo-Carboniferous.*—These rocks consist here of glacial conglomerates and sandstones, and present some differences in their powers of resisting erosion. They are for the most part either level bedded or gently dipping, and grade from very coarse conglomerates down to almost uniform fine sandstones. Their investigators state that rocks of this age had a variety of origin—glacial, fluvio-glacial, and probably lacustrine. In places the rocks are much compacted and indurated, as at the mouth of Werribee Gorge, where they occur in part as steep cliffs.

At other points we get friable sandstones, giving us rounded grassy hills, and wide U-shaped valleys, as in the lower Korkuperrimul (Lyell's Creek) and Bald Hill at Bacchus Marsh. The higher parts of Bald Hill, especially where the dip of the beds is most marked, present a very barren appearance, bare rocks being exposed over large areas. All the extensive outcrops of glacial are within the let-down Block B, except a few which have been similarly preserved in the N.W. corner of the relatively depressed block E. In the north of block B, we also get both types, the very hard rock giving up the high bluff near Glenpedder homestead, and the more friable material providing the pleasant rounded hills of

Greendale. The glacial deposits are estimated to have a maximum thickness of over 2000 feet (ref. 12, p. 269), and their base is exposed in many places. They are rarely stratified, are well jointed, and are intersected by numerous dykes, now largely decomposed. These dykes may be seen typically at the North quarry in Greendale, along Dales' Creek, and in the bye-wash cutting at Pyke's Creek reservoir.

The "glacial beds" are much less resistant than the Ordovician rocks on which they rest. Almost all trace of these has been denuded from the higher peneplaned surface of Block A, but the finding of undoubted large glaciated pebbles on the caps of the ridges north of Greendale, proves the previous existence of such deposits there. Mr. C. C. Brittlebank, has also kindly taken the writer to various small patches of undoubted glacial conglomerate, each a few square yards in extent, on the topmost ridges of the Lerderderg Ranges, about 1000 feet above the bed of the Lerderderg River (where it enters on the flats). It would appear from the evidence in this area that the glacial only survived the peneplanation where it had been faulted down, or else persisted, as stated above, in small patches, probably in old valley bottoms in the Ordovician.

(d) *Older Basaltic lava flows.*—This rock is generally described as of lower to middle tertiary in age. Messrs. Hall and Pritchard believed it to be "Eocene," but other geologists place it higher in the series, approximately "Miocene." The rock is usually a dense black basalt, and is mainly preserved in this area by faulting (Greendale and Bacchus Marsh), or faulting and warping (Maude). The question of the age of these lavas is briefly discussed in later portions of this paper.

Where it outcrops, it forms well rounded hills (Fig. 20), and provides excellent soils, which add much to the fertility of the localities mentioned. Beds of tuff, sometimes a bright red, occur in the series, and are to be well seen where the Myrniong-Greendale road crosses the Korobeit Creek. There appear to have been numerous flows, which in places may be seen tilted at various angles, especially along the right bank of the Lower Korkuperrimul, and at a point on the upper part of Robertson's Creek, a small tributary of the Lerderderg. The total thickness in this area is unknown, but similar flows occur at Flinders to a depth of 1300 feet. In their present decomposed state these rocks are easily eroded.

(e) *Middle Tertiary.*—This series includes a great variety of rock types all more or less easily eroded in places notably so. In common with other tertiary deposits of Victoria, there is no consensus of opinion as to their age; Mr. F. Chapman classes them as Janjukian (ref. 12, p. 299). They occur mainly around Bacchus Marsh and in the Parwan valley, where they have been preserved by faulting, and at Maude. At Bacchus Marsh they are probably fluviatile, and consist of gravels, sands, clays, lignites, and ironstones.

They include valuable deposits of sands and clays (Dog Trap Gully), limestone (Coimadai), and fire clays (Darley). Their resistance to erosion is feeble, and the Parwan valley, as will be shown is an example of a small creek carving out a great valley in this material in a comparatively short time. Where the ironstones outcrop, as in cuttings on the Bacchus Marsh-Myrniong road, they appear to be somewhat more resistant, but the iron is rapidly leached out, and the clayey residue is soon carried away. Valleys in these rocks are marked by the frequent occurrence of land slips. Wilkinson and Daintree (ref. 56, Note 11) comment on the very easy erosion of these beds in the Parwan valley, and attribute it largely to the high percentage of soluble salts contained in the beds, chiefly sodium chloride and magnesium sulphate.

(f) *Newer Basaltic lava flows.*—This is the most widespread surface rock in the area. It covers almost the whole of block E and large parts of B and D, as a great sheet; tongues occur on blocks A and C. As already pointed out, it has largely obliterated the old drainage system and made the reading of the progressive physiography of the area a very difficult matter. These basalts are usually widely placed in age as "Pliocene to recent." The rock is a dense, well-crystallised basalt, tuffaceous beds occur rarely (there is a good exposure in a Werribee tributary at the foot of Mount Darriwill), and the very scoriaceous material is confined to the cones. It is well jointed, very platy in places (e.g., bed of Werribee below Ballan), and may be classed as very resistant to erosion.

This estimate of course refers to the rock as it occurs in most of its outcrops, viz., either quite fresh or with negligible decomposition. It forms on the whole a comparatively thin sheet mainly under 150 feet thick with a maximum depth of about 400 feet where filling old valleys.

It is of interest to note here Mr. C. C. Brittlebank's results, published in the Geological Magazine, 1900 ("Rate of erosion of some Victorian River valleys"), and following on a series of experiments conducted in the Werribee Gorge itself. Mr. Brittlebank places these rocks in the following order :—

1. Permo-carboniferous sandstones. (Most rapidly eroded.)
2. Granodiorite.
3. Ordovician slates and sand stones.
4. Newer Basalt (Most resistant.)

(g) *Gravels, sands, slays and soils.*—This is the latest series of rocks in the area, and their period of deposition extends from the close of the newer basaltic period up to the present day. They are naturally very loosely compacted, and present slight resistance to erosion; they are found throughout the whole area as small river flats, but are chiefly developed in blocks B, C, and E. We may classify them under three heads as regards origin :—

(i.) River Deposits.—Here we must place all the river flats throughout the area, and particularly the large triangular patch at the mouth of the Werribee River, as well as that surrounding the You Yangs.

(ii.) Fault aprons.—These like the last were deposited by stream action, but are differentiated in this classification on account of their origin as alluvial aprons, extending outwards from the bases of the various dominant scarps. They occur extensively along the west of block E, in the centre and west of block C, and in the north of block B. Their exact relationship to the scarps will be dealt with later.

(iii.) As a separate case we may consider the fertile and extensive flats of Bacchus Marsh. They constitute a considerable area of the most productive soils in the State, and in summer, when all the open country of the area is dry and brown, the green flats of Bacchus Marsh may generally be detected from any viewpoint in the district like an emerald set centrally between the Divide and the sea.

(h) *Dykes of various ages.*—These occur throughout the area intersecting the lower Ordovician, permo-carboniferous, and older basalts, but were not seen intruding into any later series, although dykes associated with the newer basalt must necessarily cut through the middle tertiary beds.

These dyke rocks have not been very closely examined petrologically, and for our purposes may be roughly divided into acid and basic types. The majority of those seen by the writer were east-west, and were apparently basic; in most cases they were of lower resisting power than the intruded rock, being marked on the surface by a hollow rather than by a ridge. North-south dykes also occur, a well-known one being in the Werribee Gorge. It is a highly resistant quartz-porphyry, and has noticeably restricted the width of the gorge at the point of intersection.

VIII.—Dominant Physiographic Features.

Before entering upon the detailed description of hill and valley, we may first set out the three dominant tectonic occurrences which have governed and decided the present day physiography of this area, as well as of a large part of the State.

Firstly, a great "still-stand," during which a highly complete stage of peneplanation was reached.

Secondly, a widespread general uplift of this peneplaned area, gradual and differential. The differentially raised blocks separated along fairly sharp and straight lines, giving us fault scarps which still largely control the physiography.

Thirdly, after initiation of a new physiographic cycle, based largely no doubt on the older features of the peneplain, we had a great volcanic period when the newer basalt sheets wiped out many of the old river systems. A second period of faulting, with differential uplift, occurred. New river systems were initiated, and subsequent erosion has led to the formation of the varied series of hills and valleys, whose present day appearance now occupies our attention.

Each one of these three great features is important enough to warrant separate consideration, and since they are all excellently exemplified in the Werribee River area, we shall proceed to discuss them under the following heads:—

(a) The Peneplain, its date of completion.

(b) The Faulting, its age and effects.

(c) The Newer Volcanic Sheet, and its effects.

Other important happenings, such as the "older" period of vulcanicity, and the period of fluviatile or lacustrine deposition, are referred to in Section VII. and later sections. While these, too, played important parts in the production of the present physiographic features, the three above-mentioned happenings were found to be the dominant factors, and a separate section is therefore devoted to them.

(a) *The Peneplain, its date of completion.*

(i.) Introductory.— The writer enters on this question with the greatest trepidation, recognising the number and variety of conceptions that have already been published on the matter, and the difficult and sometimes contradictory nature of much of the evidence on which a decision must be based. In consideration, however, of close observation and critical examination of what appear to him to be fundamental points, he makes bold to advance the conclusions arrived at from a study of the physiography of this particular district.

In this area the uplifted and dissected peneplain comprises blocks A. and C (see Fig. 2), the Blackwood and Lerderderg ranges (A), and the Brisbane ranges (C). In the other blocks it has been much more dissected or obscured by lava flows. From the summits of Mount Blackwood or of Wuid Kruirk (Blue Mountain) one may get an excellent view of the typical dissected peneplain. Equally as striking views may be obtained in eastern Victoria, but perhaps none so diagrammatically perfect.

The same peneplain uplifted and dissected has been recognised all over this State, in the highland area. New South Wales physiographers refer to three distinct peneplains in their highlands, but it is in the nature of things that *one*—the last—must be the dominant one at present, since in its formation all, or nearly all, pre-existing topographic features would naturally be destroyed. E. C. Andrews (ref. 3, p. 118) emphasises this fact in his paper on "Erosion and its Significance," viz., that the formation of one peneplain must mean the complete dismantlement of any older one, assuming the work to be done in areas of practically homogeneous rocks. W. B. Scott (Introduction to Geology), also says: "In the production of new topographic forms, old forms are more or less completely destroyed." Since, therefore, the last peneplain is the important one, and since there is no recorded proof in Victoria of traces of other peneplains, it is reasonable for us to consider our one peneplain alone.

(ii.) *The peneplain as an Australian feature.*—We may now push our investigations outward to cover a wider tract of country, and the following extracts from various writers are very suggestive of the possibility, long since recognised by E. C. Andrews (ref. 1), that an uplifted and dissected peneplain, perhaps the same peneplain, is the basis of the upland physiography of every State in the Commonwealth.

Victoria.—Every local writer on physiographic and allied matters recognises the existence of the dissected peneplain in this State. Individual opinions from various papers will be quoted later.

New South Wales.—E. C. Andrews, in common with all his fellow workers in that State, accepts the peneplain as the outstanding fact of our physiography. In reference 1, p. 421, he says: "Eastern Australia was a peneplain raised but little above sea level towards the close of the miocene uprising (about pleistocene times), producing the great block faulting in the south-eastern knot."

Queensland.—J. V. Danes (ref. 15, p. 6, etc.), who chiefly worked in Queensland areas, believes, in common with Australian workers whom he quotes, that the peneplain extended from New Guinea to Tasmania and believes it "to have been divided into a large number of independent outletless basins with shallow lakes." (See also ref. 44.)

South Australia.—Rev. W. Howchin (ref. 31), the chief authority on the physiographic features of South Australia, states regarding the uplands of that State: "The old peneplain now stands at an elevation of 1500 feet, with rivers flowing mostly in juvenile gorges 300-500 feet deep." "The uplift probably coincided in the main with the Kosciusko epoch of New South Wales physiographers." (page 176).

Tasmania.—W. H. Twelvetrees (ref. 54, p. 162) states: "Since Pleistocene times the north-west part of Tasmania has apparently suffered an uplift relative to sea level, as evidenced by the existence of extensive elevated peneplains. Recent river systems have deeply dissected the area, and seamed it with profound gorges." L. Keith Ward (ref. 54a, pp. 6-18), describes an interesting portion of the dissected peneplain of north-western Tasmania.

Western Australia.—J. T. Jutson (ref. 35 p. 95) discusses all the available evidence, and concludes that the last great uplift of the broad plateau of Western Australia was pre-pleistocene and post-jurassic, probably early or late pliocene, while its reduction to a peneplain had taken place probably in early or middle tertiary times.

Northern Territory.—W. G. Woolnough (ref. 55, p. 45) states that the "Most striking feature (of the Territory) is the extent and uniformity of the plateau areas, 1000 feet or so above sea level. . . . This vast upland is a peneplain of the most perfect type and was formed by sub-aerial erosion at a time when the country stood much lower than it does at present. . . . It is trenched by numerous rivers, which have reached base-level for a long way up their valleys."

Papua.—J. E. Carne (ref. 11) does not deal specifically with the physiography, but mentions a "plateau deeply dissected by torrential streams," and further states that this plateau "in part consists of tertiary limestones of as late as pleistocene age."

(iii.) *Age of the Uplift.*—From a consideration of the above extracts and their accompanying reports, it seems justifiable to assume that the peneplanation was general over the whole continent, and that uplift of the peneplaned area to form the present highlands of Australia may possibly have taken place at very nearly the same geological period. It is generally agreed that this uplift dates somewhere between middle tertiary (miocene) and pleistocene times. The stratigraphical evidence on which the date of the completion of the peneplain is based mainly exists in Victoria. Therefore, having taken a brief survey of the extent of the general peneplanation and uplift we shall return to the problem of the date as far as it may be discovered in this south-eastern corner of Australia.

It is of course understood that we may have peneplains of various stages of completion yet each deserving of the title of peneplain. A very long period of still-stand of the land must be necessary in order to accomplish the perfect base-levelling of an area, but we appear to have had in Victoria a surface which closely approximated to that ideal. Immediately any uplift took place on the peneplain, rejuvenation of the streams would result, with dissection of the peneplain surface. The date of the commencement of uplift therefore marks the completion (or cessation) of the particular cycle of erosion which formed the peneplain.

The rocks which formed the surface of the peneplain in Victoria were for the greater part the lower and upper Ordovician, and the silurian rocks—all of which may be regarded as one rock type as far as erosion is concerned (see description of rocks, *supra*). The schists and gneisses of N.E. Victoria and the intruding granite masses also formed portion of the planed area, as did the softer level-bedded sandstones of the glacial period (Bacchus Marsh, Heathcote, etc.), the carboniferous sandstones and mudstones (Grampians, Mansfield, Mt. Wellington, etc.), and the devonian (Tabberabbera, Buchan, etc.) shales and limestones. Each of the three last named series of rocks now exists in limited areas only; they are mainly of a much lower order of resistance than the beds first mentioned, and are probably now largely preserved in patches where they may have occupied valleys and fault-troughs at the time of planation. In 1866, Selwyn (ref. 50) put forward the idea that the Mansfield-Grampians series of sandstones had once extended right over that surface of Victoria that now separates the two main occurrences. (See Section VIIa.) The numerous and scattered relics of our glacial sandstones suggest that they were formerly enormously greater in extent; there is no doubt they have been mainly preserved by faulting in the Werribee area, and in all probability close examination would reveal like relations elsewhere.

Our Victorian peneplain, therefore, was for the most part composed of hard, folded slates, sandstones, and quartzites, with accompanying gneisses and granites, the less abundant later and softer rocks being preserved only in troughs and pockets.

At some date to be decided, this extensive level surface was subjected to great forces of uplift, which have ultimately at our present day resulted in the old peneplain level in eastern Victoria standing at 6000 feet above sea-level, in the Werribee area at 2000 feet or less, gently sloping westward until at the Glenelg River, in Western Victoria, it sinks below the younger beds of the "Murray Gulf."

There are two means whereby we might attempt to arrive at a decision as to the date of commencement of uplift :—

(a) Physiographic evidence, amount of erosion during and subsequent to uplift, fault evidence, etc.

(b) Palaeontological evidence—the selection of some bench mark with which we can correlate the beginning of uplift.

(o) *Physiographic evidence.*—Both methods above referred to have been availed of. Much use has been made of physiographic evidence in New South Wales, but it does not appear to lead to very reliable results. There are enormous variations in the amount of erosion accomplished during the same period at different points in this State.

(i.) At Dargo High Plains we have steep valleys 1500 feet in depth cut since the beginning of the uplift, and Mr. Herman (ref. 29 and 30) refers on page 339 to "3000 feet of vertical Cainozoic erosion" in that area.

(ii.) At Mount Buller (ref. 19, p. 396), the Howqua and Delatite have cut valleys nearly 4000 feet deep into similar hard slates and granites during the same period.

(iii.) In the Werribee area we have the Lerderderg, with its long and precipitous gorge, cut over 800 feet deep into very hard folded slates. This is much less than that accomplished in eastern Victoria, and shows how the factor of elevation affects the result.

(iv.) Meanwhile, we have the Werribee, above Bacchus Marsh, cutting a gorge about 700 feet deep in quite similar rocks subsequent to the Newer Basalt period, presumably a considerably shorter time.

(v.) Parallel with the Werribee is the small tributary of the Parwan excavating during the same time a great valley—much wider and deeper than that of the parent stream. (Figs. 24 and 30.) This result is due to the fact that the Parwan is working in softer rocks.

Since such enormous variations may be due to differences in elevation and rock-resistance, and since there are no means of knowing either factor quantitatively for any contrasted streams, this physiographic method does not seem to be of very great value in Victoria. Mr. Andrews has informed me, in a letter, that his later judgment and experience enable him to realize very fully the great variations in topography that may be wholly due to differences in the resistance to erosion that exist between different rock types.

There is another physiographic method of determining the date of uplift, and that is to fix the age of the fault scarps formed during such uplifts; the writer has followed this method with some success, as will be detailed later. (Sect. VIII., (b), (vii.)).

(b) *Palaeontological evidence.*—The second method, and the more reliable, is to make an effort at correlation with known fossiliferous beds. Here we have the difficulty of the lack of agreement as to the various ages of our well-known and much discussed Victorian tertiaries.

Dotted over the eastern Victorian highlands we find ridges and mountains standing at the general level of the old peneplain, capped and preserved by the remnants of basalt flows. These flows have been classed together as "Older Basalts," and correlated in time with older basaltic flows in the Melbourne and other areas. Somewhat loosely, and in a general way only, these occurrences of older volcanics have been correlated in age with one another, and with those of New South Wales and Queensland (ref. 45). As pointed out by Professor Skeats (ref. 47, pp. 199-201), in dealing with these older volcanic rocks, within the State of Victoria, the relationship of these rocks, with fossiliferous beds is weak, even where both are exposed together in one section. The weakness of the evidence is due to two factors:—(a) the stratigraphical relationships are not constant, the basalts being variously above, below, or interbedded with the fossiliferous beds, according to locality; (b) neither the correlation nor the precise geological ages of the associated fossiliferous beds are definitely agreed upon. Professor Skeats adds: "Many of the occurrences are separated by considerable distances from basalt whose age can be demonstrated and in these cases considerable doubt remains as to whether they are correctly referred to the "Older Basalt," and if so, as to whether they are contemporaneous, or part of a series of eruptions extending over a long period of time."

The correlation of the ages of the Victorian basalts with those of New South Wales and Queensland seems to be even more a matter of conjecture. The main argument apparently is that where the general relations seem to point to basaltic lavas belonging to an older tertiary period, a correlation in age with the older basalts of Victoria is assumed, the grounds for such assumption being that since Eastern Australia appears to be a fairly compact tectonic unit, it is likely that the volcanic periods of the different States would be, in general, closely related in time.

It is unfortunate that much of the past physiographic work done in New South Wales has as far as time is concerned, been based on the assumption that the ages of the Victorian basalts and tertiaries were generally agreed on. The matter recurs in other parts of this paper, and is there discussed from the other points of view.

Having noted the above deficiencies in our knowledge of the ages of Victorian tertiary rocks, the writer feels the necessity for defining his beliefs in the matter. After a careful consideration of the evidence, therefore, it is here assumed, with the cautions already pointed out, that the older basalts of Greendale and Bacchus Marsh may be sufficiently closely correlated with those of Maude, Keilor, and Royal Park, and with the general mountain-capping basaltic remnants on our eastern highlands, to refer them to a period, called the Older Basalt period, and denoting a more or less extensive term of vulcanicity, which occurred at a time variously estimated as from lower to middle tertiary (Barwonian). This divergence of opinion as to age is largely due to the uncertainty that exists regarding the age of our fossiliferous tertiaries.

If these older basalt flows of our eastern highlands had been poured out while the area was still of somewhat high relief—i.e., some time before complete peneplanation—they would scarcely have been preserved to-day as we now find them. Moreover the valleys which these basalt flows have filled and preserved have been investigated in some places and prove to be of mature types. The fact that these basalts in eastern Victoria lie at, or a little above, peneplain level, appears to show that there could not have been a very long interval between uplift of the peneplain and the extrusion of the basalt. Otherwise we should expect to find these lavas, where preserved, somewhat below the general peneplain level. (See also Hart, ref. 22, p. 256.)

This leads to the conclusion that the completion of the peneplain (the commencement of the uplift), must have been very close in time to the extrusion of the older basalts. R. A. Daly (ref. 14, p. 193, etc.), suggests that lava flows tend to *follow* the initiation of movements of uplift and instances the pliocene and postpliocene basaltic sheets of Syria, Great Basin (U.S.A.), Idaho and Iceland.

We shall assume that the older basalt flows were closely associated in time with the first uplift of the great planed blocks that form our Victorian highlands.

Now the older basalts are closely associated with richly fossiliferous beds :—

(1) They overlie the plant-bearing deep leads of the Dargo High Plains, etc.

(2) They underlie the thick "Cinnamon and Laurel" leaf beds at Bacchus Marsh and Parwan.

(3) They underlie the rich marine beds at Royal Park and Keilor (Melbourne).

(4) They are interbedded with marine limestones at Maude and other places in the lower Moorabool.

Unfortunately in all these cases they are associated with the beds concerning which essential differences of opinion exist between our palaeontologists. It is agreed, however, that these deposits are mainly of middle to lower tertiary age; eocene (Hall and Pritchard, Tate and Dennant), or miocene (McCoy, Chapman, Gregory, Newton, etc.). Following this line of argument, the initiation of the great uplift would certainly not be younger than, say, Miocene. The chain has many weak links but under present circumstances is as near as we can approach to the truth.

Moreover, since the writing of the preceding argument some few months ago, two very interesting cases of strong corroborative evidence have come to light—one of them following on personal observations in the field, and the other published by Mr. F. Chapman. These will be referred to later.

In New South Wales the general opinion (Sussmilch, Geology of N.S.W.), seems to be that a great epeirogenic uplift took place, and "ushered in the Tertiary period." Then followed the older basalts and a cycle of erosion which formed the "Great East Australian Peneplain." Then a small uplift, followed by the outpouring of the newer basalts, and, finally, in what is called the "Kosciusko epoch," another great epeirogenic uplift, with block faulting, and immediately followed by the Pleistocene period (ref. 48, pp. 208 et seq.).

Andrews (ref. 1, p. 457) believes that the peneplanation in New South Wales, by analogy with that of Western America, may be assigned to tertiary times, and that the block faulting, plateau forming, and gorge carving may be assigned to the Ozarkian or Sierran (Pleistocene age).

(c) *Previous work on this matter in Victoria.*—It will be of advantage to examine the results arrived at concerning this matter by various independent workers in Victoria.

J. T. Jutson (ref. 33) deals with the Nillumbik peneplain, near Melbourne, a less uplifted portion of the great peneplain. He proves that the uplift there was differential and gradual, and believes that the older basalt of Kangaroo Grounds was erupted prior to the completion of the peneplain.

T. S. Hart (ref. 22, p. 272) believes our highlands "to be due to the unequal block elevation of a Mesozoic or early Tertiary peneplain, with subsequent extensive modification by denudation and volcanic activity."

D. J. Mahony (ref. 39, p. 377) speaks of our highlands as "a dissected peneplain," differentially uplifted. He postulates a long pre-Miocene period of quiescence followed by a great uplift, with vertical movement. He believes the older basalts to be associated with the first great period of earth movements, while the newer basalts "mark the close of the last great movement that elevated our Victorian Kainozoics."

Professor David (ref. 12, p. 287) sums up thus: "In either very late Pliocene, or very early Pleistocene time, the earth's crust, in the Australian and New Guinea region, was subjected to considerable diastrophism. The eastern periphery of Australia, including Tasmania, was warped up to altitudes of over 3000 feet above the sea."

Professor Skeats (ref. 47, pp. 188-189) suggests that the first peneplain uplift in Victoria was post Mid-Kainozoic, followed by later uplift and dissection, with consequent formation of another, *the* peneplain; the present surface features being the result of a still later uplift and consequent erosion. Professor Skeats also suggests (B.A.A.S., 1914, p. 360), a post mid-tertiary age for the "succession of elevatory movements of the plateau type," that have affected the Omeo district in eastern Victoria.

N. R. Junner (ref. 36), who also investigated the Nillumbik peneplain, believed the uplift to be Kalimnan, and to have been differential and gradual, without faulting in that area.

Jas. Stirling (ref. 51), writing thirty years ago, on an area in our Eastern Highlands, says: "That a vast tableland existed in Miocene times, stretching from Mt. Buller to Mt. Kosciusko, and of which the Omeo plains and Maneroo tablelands are visible remnants, seems to be abundantly proved. Powerful erosion has subsequently excavated deep valleys, which now break up these once extensive tablelands." Mr. Stirling was aware of the gradual uprise of the land as a factor in deepening the rivers, but he wrote of these facts at a time when our present physiographic terminology was scarcely known.

The question appears to gain in complexity as one studies the individual viewpoints of other investigators. For reasons already stated, the writer can see definite proof of only *one* great peneplanation in this State. Two or three scattered monadnocks, of somewhat similar height, can hardly be called in as evidence of a prior planation. They would perhaps owe their existence to superior resistance, and if plutonic, may not even have been uncovered at the conclusion of a previous base-levelling of the area.

Various writers referred to have demonstrated, and all agreed, that uplift was very gradual. Undoubtedly also there were periods of no movement, and in some localities periods of depression. Jas. Stirling (ref. 51) refers to thick terrace alluvials on the sides of the Tambo, high above the present level of the river; these bear witness to a more or less sustained period of still-stand, with consequent deposition. Similar terraces occur in the Goulburn, and the writer has examined relics of such terraces high up along the valley of the Lerderderg, where three series occur. Depression must also have occurred in parts of the State, as pointed out by D. J. Mahony (ref. 39, p. 377), in order to allow of the deposition of our marine Kainozoics. The great depth of tertiaries in the Sorrento bore (1696 feet) and the still more unexpected result at Portland, where 2265 feet of the tertiaries were penetrated, without reaching the bottom of the series, (ref. 40), prove extensive kainozoic depression. Such depressions were to some extent local, and occurred in conjunction with the progressive uplift of the neighbouring highlands.

(d) *Conclusions.*—Regarding the completion of peneplanation of a large resistant rock area as an event of at least a similar order of magnitude, in time, as a geological period of sedimentation, and possibly of rarer occurrence, the writer's present conclusion is that the peneplain represented by the present level crests of our Victorian highlands—grading from 6000 feet above sea level in the east, to a few hundred feet in the west—was completed about the time of the older basalts (? Miocene), when the first important uplift took place. This may have gradually continued, with intermissions, but in a period subsequent to or contemporaneous with the newer basaltic eruptions, there was a second considerable movement of uplift.

This last movement would seem to coincide with the later dates (Kalimnan and Pleistocene) arrived at by the majority of previous writers.

The proofs produced in the next section, regarding the ages of the faults in the area under discussion, bear closely on this question.

(b) *The faulting, its age and effects.*

On the occasion of the reading of a paper before the Royal Society of Victoria in 1913 (ref. 19), in which extensive block faulting was postulated on purely physiographic grounds, the then President of the Society tendered to the writer a kindly caution against accepting large faults in any area without abundant proofs, especially those of a stratigraphical nature. This advice has tended to make him very cautious and critical in his working out of the faults of the Werribee River area.

Experience in the field, however, combined with reading on this matter, and consultation of maps and sections from various closely-mapped areas in this country and others, leads to the conclusion that, in addition to the few dominating faults which will be clearly demonstrated in this paper, abundant other faults, of less extensive movement, occur. The conviction is here expressed that block B, and especially the complex Bacchus Marsh area, will be proved on more thorough knowledge to be a mosaic of small faulted blocks.

New South Wales has ever taken the lead in Australian physiographic questions, and there the most able exponents, David, Andrews, Taylor, and others, abundantly demonstrate block faulting as an important feature.

Mr. Andrews, however, among much generous advice tendered to the writer by letter, states that his more mature views are that "Epeirogenic uplifts and differential erosion have been the key to the tertiary history of Eastern Australia, with block faulting as a subordinate feature."

In his interesting Physiography of Western Australia (ref. 35), Jutson describes the great Darling fault scarp, extending for 200 miles, as well as others of lesser importance. In South Australia we have the accepted rift valley of Lake Torrens, and the definite block-faulting of the Mt. Lofty ranges; while between Victoria and Tasmania is the great and generally accepted sunkland of Bass Strait.

In Victoria, also, T. S. Hart, commencing with the diagrammatic example of block faulting in the Grampians of the west, has proved the same features to continue eastward along the Divide as far as Ballarat (refs. 22, 23). It is unfortunate that the Grampians themselves have not been more closely and critically studied from the physiographic viewpoint.

Jutson (ref. 33), on carefully collected physiographic evidence, has demonstrated certain faults in the middle Yarra area, and has suggested the presence of others. Morris (ref. 38), in his paper on the Geology of the Lilydale area, expresses his belief that the geological evidence there points to the existence of important faults.

The mining fields of the State—Ballarat, Bendigo, Steiglitz, Blackwood, and Wonthaggi, etc.—show abundant faulting in their detailed mine plans and sections, while to miners in our fields strike faults ("Slides," etc.), and dip faults ("Cross courses") are very well known features.

The relief of the Werribee River area has been almost wholly decided by differentially uplifted blocks of country (as already mentioned), separated by well-defined scarps. Of these the two most important may be called :—(a) the Rowsley or Bacchus Marsh scarp, and (b) the Greendale scarp.

The faults (demonstrated or suggested) referred to in the following pages are set out in Fig. 5, where they are given alphabetical symbols for simplicity of reference. They will be dealt with in the following order :—

(i.) The Rowsley or Bacchus Marsh Fault.
(ii.) The Greendale Fault.
(iii.) Minor Faults.
(iv.) Previously demonstrated faults.
(v.) Suggested fault.
(vi.) The Sunklands.
(vii.) Final conclusions as to age.

(i.) *The Rowsley, or Bacchus Marsh, Fault.* (see a, in Fig, 5).—One of the least impressive portions of the scarp which marks this important line is perhaps its most widely-known part, namely, the basalt-covered slope lying westward from Bacchus Marsh, and up which the Ballarat-Melbourne railway line ascends by a horseshoe-shaped loop, 6 miles in length (see Plate XI.). It has been observed by practically all later Australian geologists, and a few references thereto are to be found in current literature, but excepting the observations by Mr. Hart (ref. 22), no detailed work has been done on it.

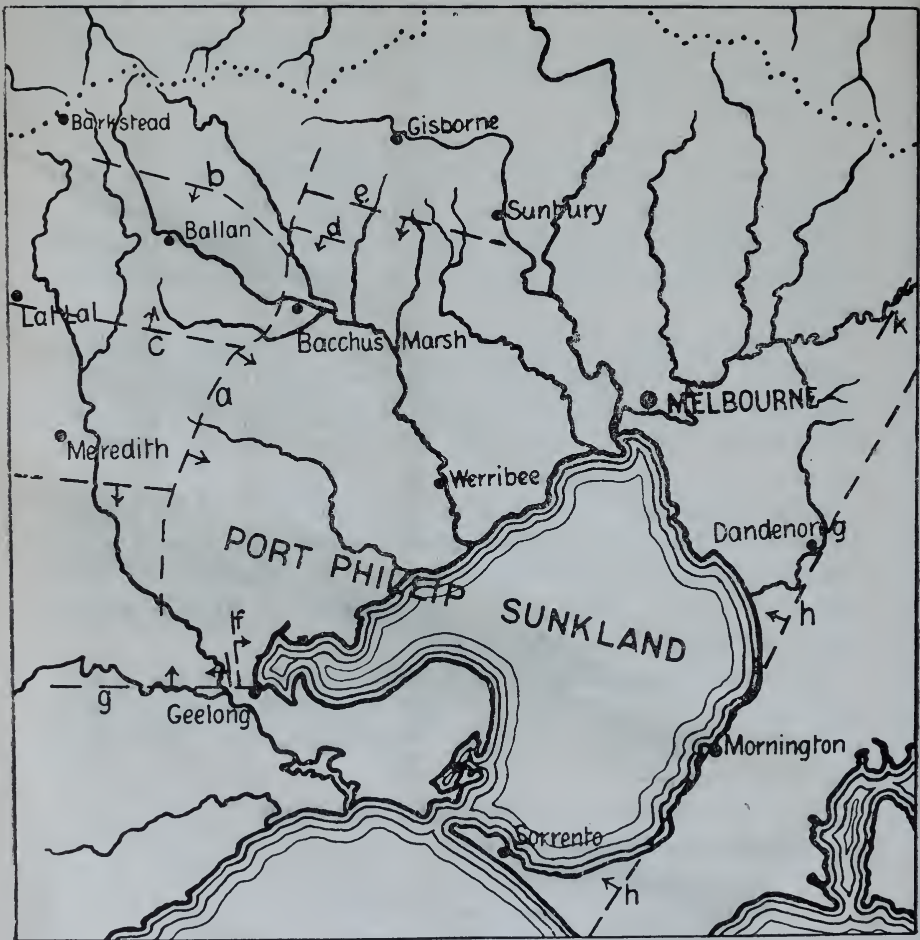


Fig. 5.—Map of the surroundings of Port Phillip Bay, showing the positions of the chief demonstrated, suggested, or generally accepted faults. These are shown by broken lines, and lettered alphabetically as per context (Section VIIIb). The directions of downthrow are suggested by arrows.

The scarp is really about thirty miles long, and is economically and topographically the most interesting feature of the whole area under discussion. It acts as a barrier between the lower early-settled plains of the lower Werribee and the important agricultural and mining centres of Ballan, Ballarat, Blackwood, etc. It presents a difficult problem to the engineer, and while the railway has ascended by an extended loop, the climb is still difficult, and extra power is required to carry trains up the stiff rise of 1300 feet from Bacchus Marsh to Ballan. The main road also takes a devious course, along the valley sides, but it, too, still presents sustained and difficult grades to the traveller.

The following opinions have been advanced regarding this scarp :—

(i.) Professor J. W. Gregory (ref. 21), in the introductory chapter of his Geography of Australia, states :—

"The high bank to the west of Bacchus Marsh, 1000 feet in height, up which the train climbs on the way from Melbourne to Ballarat, is one of the oldest, well-preserved valley walls in the world. It was carved out by river erosion in Silurian times. It was in existence before the materials of which most of the Alps are built had been laid down in the seas of central Europe. It was old before the first bird or mammal or reptile had been born upon the earth, and it dates back earlier than the building of the lands whose foundering formed the Atlantic Ocean. That old valley wall at Bacchus Marsh remained long hidden beneath sheets of sand, gravel and clay, the partial removal of which has once more rendered it an important feature in the Australian landscape. It has again been protected by a cascade of molten lava that poured over its edge from the volcanoes of the plateau behind it; and that coat of rock has given a renewed lease of existence to this venerable geographical feature."

Notwithstanding the literary merit of this account, the fact remains that the structure and materials of which this scarp is built at Bacchus Marsh quite preclude the possibility of its being older than Middle Tertiary. Ancient glacial valleys, to which the Professor's fine description may be applied, are elsewhere exposed in section in this district, as set out by Messrs. Brittlebank, Sweet and David (ref. 7).

T. S. Hart (ref. 24), in some notes in the Students' Magazine of the Ballarat School of Mines, of a few years ago, briefly refers to the scarp thus :—"The edge of the high ground here was probably determined by a fault scarp not altogether obliterated by newer lava flows, and well marked in the boundary of the Ordovician rocks south of Rowsley."

The same writer (ref. 22, p. 26), believes that, at a point east of Trig Hill, Bacchus Marsh, "there is a monocline probably faulted, and further south along the edge of the high basaltic plateau, a fault scarp over which the lavas have flowed." He refers to its southern continuation, as indicated for about six miles on Quarter Sheet 12 S.E., and states: "As the line of fault passes between the old township of Rowsley and the railway station of the same name, I will call it the Rowsley fault."

In a map of the "Tectonic Features of Australia and Tasmania," accompanying Professor David's article on the Geology of the Commonwealth (ref. 12), there is a large E.W. fault shown, with a down-throw to the South; it is labelled "Bacchus Marsh Fault," and is evidently intended to indicate the northern boundary of the "Great Valley of Victoria." The Bacchus Marsh scarp, however, really runs almost north and south (see Fig. 5), and the series of E.W. faults that probably bound the "Great Valley" yet remain to be investigated.

Wilkinson and Daintree (ref. 56), in the sheet of notes attached to Quarter Sheet 12 N.E., refer to the scarp at Bacchus Marsh, and say:— "A similar feature must have existed in the Miocene formations prior to the flow of newer basalt, which has evidently flowed over a steep face 200 feet in height." The origin of the scarp is not discussed.

Professor Skeats (ref. 47, p. 208) also mentions this scarp, and says:—"It may be formed by denudation or may represent a fault scarp formed during the eruptive period."

Andrews (ref. 1, p. 477) refers to the "Bacchus Marsh Fault" as one of uplift, and adds: "Not yet examined carefully. It is a dismantled scarp to the north of Bacchus Marsh. Some of the associated basalts are older and some younger than the scarp."

The writer has carefully examined this scarp along nearly the whole thirty miles of its length, and has been greatly aided by the geological survey maps of the area, coupled with the contour maps of the Military Survey. He must confess to a regret that he was unable to examine the scarp with closer detail in the immediate neighbourhood of the Anakies, and in the few miles of more inaccessible country in the extreme north. He is confident, however, that such examination would only further confirm the results already arrived at.

Physiographic evidence.—The line of the scarp is almost straight, but, as shown on Fig. 5, is slightly concave to Port Phillip Bay. The general height of the scarp is considerable. The levels, indicated by 100 foot contours, as shown in Fig. 6, are copied, by permission, from the Ballan and Meredith Sheets of the Military Survey. These plans give the most exact interpretation possible of the line of the fault, based on geological and physiographic evidence, confirmed in the field. Smaller contour intervals greatly emphasise the scarp.

One may approach the scarp in a direction normal to it at any part from the east, and travel twenty to thirty miles from sea level to reach an average elevation of 500 feet at the base of the scarp, a mean grade of 20 feet to the mile. Continuing in the same line, the next mile of progress would carry us up to over 1300 feet, a grade of 800 feet to the mile. Once on the plateau, we may proceed westward another twenty miles at a mean elevation of 1500 feet, an average rise of ten feet to the mile. (See Fig. 12).

The height of the scarp is greatest towards the northern part (about 900 feet), where it bounds the eastern face of the Lerderderg Ranges. It is best demonstrated along the fifteen miles running south from the Parwan area (average height here 800 feet), and is least pronounced at Bacchus Marsh (about 300 feet), and at the southern end, near the junction of the east and west branches of Sutherland's Creek (about 200 feet). Scaled sections across the scarp at various points are included in the portion of this paper that deals with the geological evidence.

The effect of the scarp has naturally been to give the established rivers on the higher block greater eroding powers. On the lower block the rivers all flow at even grades across the plains, while above the scarp deep precipitous gorges are the rule, especially in the hard Ordovician slates and sandstones. The Lerderderg gorge, at the point where that river crosses the fault, is nearly 1000 feet deep. The Werribee Gorge, one of the best-known scenic features in the area, is much more precipitous than that of the Lerderderg, and is up to 800 feet deep. Still further south, the "Anakie Gorge," on a tributary of the Little River, is about 700 feet deep where it crosses the fault. In all cases the rivers immediately pass, on leaving the gorges of the higher block, to shallow channels cut into alluvial material.

The multitude of minor streams which seam the scarp face, heading back at high grades into the higher block, closely approximate, in the nature of their valleys and spurs, to those outlined by

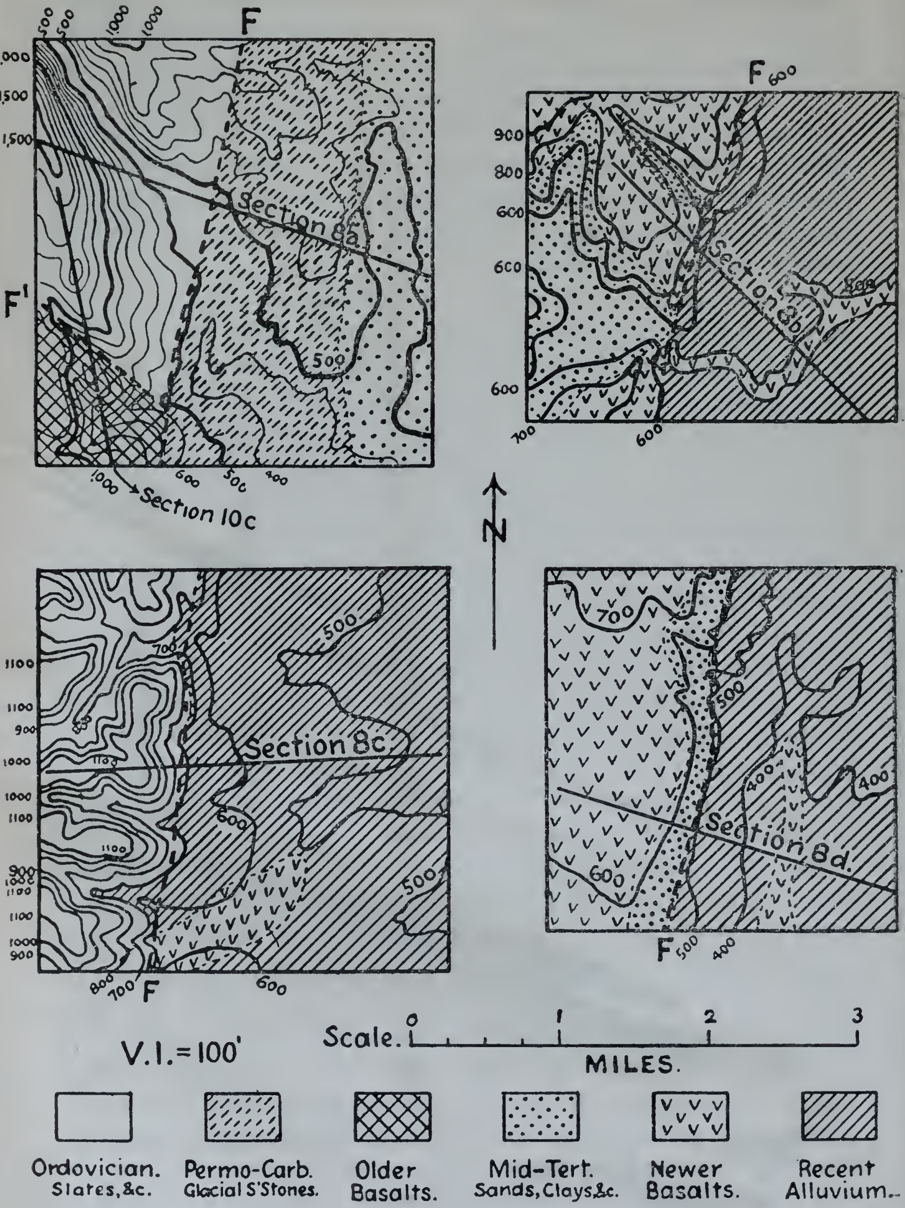


Fig. 6.—Plans of typical and critical portions of the Rowsley or Bacchus Marsh fault, showing 100-foot contours and general geology. The lines of the sections shown in Figure 7 are also indicated. F — Rowsley Fault; F1 — Greendale Fault. The localities are: a — near the mouth of the Lerderderg gorge; b — near Dog Trap Gully, Bacchus Marsh; c — north of the Anakies; d — south of the Anakies.

Professor Davis in his ideal diagrams of fault-block erosion (ref. 16). They are most definitely observable in the field, even if only noted from the plains when one travels along parallel with the scarp, as may be done along the foot of the Brisbane Ranges, or along the road from Bacchus Marsh to Bullengarook.

The physiographic facts alone thus provide strong presumptive evidence of the scarp being due to a fault. All along the base of the scarp, streams have deposited an apron of alluvium. This extends outward into the lower plains; it is usually over a mile in width, and in places reaches outwards for greater distances.

Geological evidence.—We may now examine the geological evidence for further proof, and especially for indications of the probable age of the fault with regard to the newer basalt.

The general geological relations may be seen from the plans in Fig. 6. We see that the higher blocks to the west of the scarp (A, B, and C, Fig. 2) are mainly of Ordovician rocks. On the lower side no Ordovician occurs close to the scarp base. In fact the only Ordovician whatever on the lower block E is that along the Pyrete and Djerriwarrh Creeks, and is exposed in valleys several hundred feet lower than the smiliar rocks to the west of the scarp. The boundary of the higher Ordovician is, moreover, quite sharp and almost straight, and cuts obliquely across the strike of those highly folded beds. The strike averages nearly due north, while the sharp junction with the various younger beds averages about 15° E. of North.

Four sections are shown in Fig. 7 (8a, 8b, 8c and 8d), drawn to scale normally across the scarp where the relations can be most clearly proved. It is natural of course that the lower margin should be in many places obscured by alluvium, as shown in the geological plan. The newer basalt sheet in places also partly obscures the fault. At least five important sections, however, may be examined where the true relationships with the newer basalt are shown. Such sections are especially interesting in so far as they have an important bearing on the age of the fault.

Section 8a shows the most northerly section that was critically examined, at a point where the Lerderderg River emerges from the ranges. It shows the glacial conglomerates let down and preserved to the east, along with middle tertiary beds, the latter being capped by the basalt of the Bullengarook flow. On the summit of the ranges here, small glacial remnants occur. These relations provide strong confirmatory evidence of a big fault.

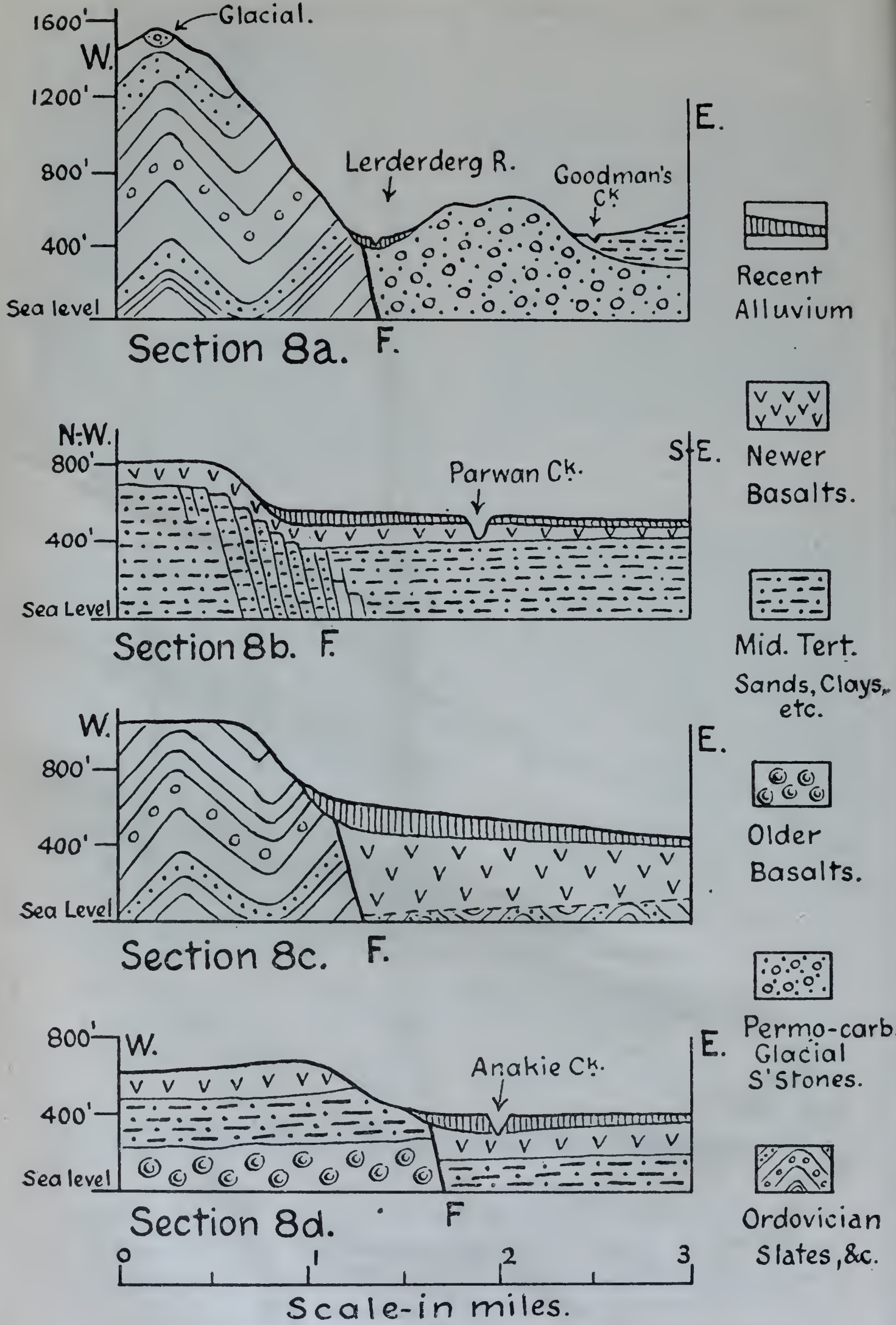


Fig. 7.—Sections across the Rowsley Scarp, along the lines shown in Fig. 6, showing geology and relief. F — Fault.

Where the Werribee river cuts the scarp, soft tertiary materials abound, and the wide, soil-covered valley slopes do not provide any good sections. A point east of Trig Hill, however, attracted the attention of the survey in 1868 (ref. 56), and has also been examined and commented on by Mr. Hart. The usually level tertiary beds here show an easterly dip, possibly due to "drag" along the fault line. Mr. Hart expresses somewhat the same idea by calling it a "faulted monocline." (ref. 22, p. 268).

A little further south there are three important sections:—(i.) on the right bank of the Dog-Trap Gully, above the railway line, (ii.) on the right bank of the Parwan, where it crosses the scarp (referred to in 1868; note 16, Quarter Sheet, 12 N.E.), and (iii.) in the cutting where the road passes over the eastern ridge into the Parwan Valley, a short distance to the south of the last point. The sum of the observations at these three points was that the basalt capping the higher block along the edge is now very thin, that the tertiaries remain on the whole level-bedded close to the edge of the scarp, and that the junction between the two thence descends steeply eastward. These relations are diagrammatically shown in Section 8b. The "Parwan Creek" shown in this section indicates the small valley cut into the alluvial and basalt by the lower Parwan, east of the scarp.

The Dog-Trap Gully is of further interest, inasmuch as it exposes along its left bank the side of a thick body of basalt that apparently fills an old valley which once existed there.

Section 8c shows the typical relations of the scarp face further south along the eastern wall of the Brisbane Ranges. The relations immediately at the foot of the scarp are somewhat hidden by alluvium, but stream sections show the volcanic sheet, in places, continuing up to the scarp. We cannot be sure that it does continue everywhere sharply up to the edge of the Ordovician, but a shaft sunk by the Geological Survey (Quarter Sheet 12 S.E.), in the alluvium about one and a-half miles east of the scarp, bottomed on basalt at 42 feet. If the basalt of the lower plains, at this point, ever existed on the top of the higher Ordovician block, we might expect to find evidence of this fact in the alluvium lying on the volcanic sheet near the base. In this connection it is of interest to note that Wilkinson's survey party, in 1863, in the shaft just referred to, found and recorded basalt boulders at depths of 13 ft. 6 in., 26 ft. 6 in., and 28 ft. 9 in. It is of course possible that these boulders were derived from the denudation of the low basaltic hills to the east of the scarp, and carried thence by stream action.

Similar boulders, if found to occur generally over this alluvial area, at such varying depths, would point to the one-time existence of basalts on the high land to the west of the scarp, where Ordovician is now exposed.

Further south at Anakie Gorge, right bank, decomposed igneous material banks close up against the Ordovician face, with a high angle junction; the volcanic material undoubtedly continues right up to the base of the scarp at this point. (Fig. 7, Sect. 8c.)

Section d is a section through the scarp at about the locality of O'Neill Bros.' farm, some five miles south from Mt. Anakie, and east of the village of Maude. The higher basalt shows an even, level, lower margin right to the edge of the scarp, and reappears on the plains below, where exposed by the Anakie Creek (east branch of Sutherland's Creek). The Anakie creek here flows parallel to the fault, a little to the east, and receives its main tributaries from the high scarp bank to the west.

There is no need to further enlarge on the proofs of faulting as shown by the sections. The evidence is quite sufficient to fully justify us in finally accepting this scarp as due to an extensive fault. We shall retain Mr. Hart's name of the "Rowsley Fault," although it may appeal more widely to geologists as the Bacchus Marsh Fault.

The age of the fault, on geological evidence, is undoubtedly post-Ordovician, post-permo-carboniferous, post-older-basaltic, and post-middle tertiary, since it has intersected and thrown down all these formations at various points. Both Wilkinson (ref. 56), Hart (ref. 22), Gregory (ref. 21), and Andrews (ref. 1), believed the feature to be pre-newer basaltic. If so it is scarcely credible that the level-bedded and very easily eroded tertiary sands as shown at Dog-Trap Gully, etc., could have preserved, for even a brief period of time, the steep face shown in section (Fig. 7b). Moreover, the sharp junction with volcanic rock at the base of the scarp at Anakie Gorge (Fig. 7c), and the section as shown at O'Neill's (Fig. 7d), at the southern end of the fault, when considered in conjunction with the sections as Dog-Trap Gully (Fig. 7b), provide fairly conclusive proof of its origin having been post newer basaltic.

The basalt-filled valleys above the scarp, now exposed in river sections, are comparatively shallow, suggesting that the area had not been uplifted prior to the basalt flows.

There is, however, another possibility of which mention should be made. In the absence of decisive proof (in the immediate neighbourhood of Bacchus Marsh) of the pre-newer basaltic origin of the scarp, we must admit the possibility of the fault having occurred during the newer basalt period. The lavas along the southern part of the scarp, east of Maude, etc., must have been poured out, prior to the faulting, while those near Bacchus Marsh may have, in part, been poured out during its formation. Professor Skeats, as already quoted (ref. 47, p. 208), suggests that the scarp may have been formed "during the eruptive period," while Mahony (ref. 39, p. 377), refers to the possibility that "the newer basalts mark the close of the last great movement which elevated the marine Kainozoics."

The scarp at Bachus Marsh was viewed by Professor W. M. Davis, during 1914, and discussed by him with Dr. Summers. The latter gentleman informs me that the Professor's suggestion was that, if a fault, it was post newer basaltic, since a basalt flow could not, from its mobile nature, have clothed the scarp as it appears to-day. This expression of opinion, from so great an authority, must be accounted as valuable evidence against a pre-newer basaltic age, especially when the available evidence of the sections examined so strongly favours the belief that the newer basalt sheet was present when the fault occurred.

It must be admitted that the appearance of the slope, where the rocks are exposed on the right bank of the Parwan (Note 16, Quarter Sheet 12 N.E.), (see Fig. 32), gives an impression that the basalt "flowed" over the slope. It may be that in these tertiary clays and sands, with their strong covering "roof" of basalt, we did not get a sharp line of fracture in all places, but rather a zone of fracture, in places of a monoclinal nature, to the slopes of which the basalt sheet accommodated itself by movements along its very abundant joints and cracks. (Fig. 7b.) However, the sum of the evidence, as already shown, favours a post-newer basaltic origin.

Notwithstanding our lack of knowledge concerning the rate of erosion in the various rocks, it is permissible to say that the physiographic evidence also points to a comparatively late age for the scarp.

Other hypotheses have been put forward regarding the origin of this scarp—that it was an old sea cliff (ref. 6), a river cliff, etc. These ideas were kept in view when examining the scarp, and there has been found not the slightest evidence in favour of any other explanation than that of faulting. To briefly recapitulate the facts as seen in the field, we may once more take a rapid survey of the whole line.

Beginning near the southern end, north of the River Moorabool, we find the fault represented by a "bank" or scarp, from 200 to 300 feet high on the western side, geologically distinct from the lower plains to the east. Where the line crosses Sutherland's Creek and the Moorabool River, two very distinct formations (the older basalt and the "thin, persistent limestone band") are abruptly cut off, and appear only on the up-throw side of the fault (see Geological Quarter Sheet 19 S.W.). To the south of these points the scarp has not been traced, and apparently disappears. Continuing northwards we find the scarp capped by newer basalt, which reappears 250 feet lower on the down-throw side, partly covered by an apron of alluvium. The cutting off of this volcanic sheet appears to have been quite abrupt.

Further north we have the high peneplain (1300 feet average) of folded Ordovician slates to the west, abruptly descending to a volcanic plain (500 feet average), with a characteristic alluvial apron along the base of the scarp. The cutting off of the Ordovician is along an almost straight line, which runs obliquely across the strike; the general height of the scarp face here is 800 feet. At the Anakies we find that a resistant granite mass in the let-down block, near the scarp, and a piling up of volcanic material below and on the fault line, has somewhat obliterated the straightness of the junction, and has made it possible to carry a road from the lower plains to the top of the ranges on the west.

Beyond the Anakies, at Anakie Gorge, the low basalt (5-600 feet) comes abruptly to the edge of the Ordovician slates, which then rise at once to a general level of 1350 feet. From this point on to "Greystones" (near the top of Quarter Sheet 12 S.E.), the physiographic evidence is excellent; deep gorges score the face of the high resistant scarp, and the streams continue on the lower block, in wandering shallow channels across the alluvial apron, to the basalt plains.

Further north, the nature of the country alters completely, the fault line turns north-easterly, and then again more northerly through Bacchus Marsh. Newer volcanics mask the scarp, except where exposed in sections. The Parwan and Werribee have cut deep into the uplifted block and show the geological structure west of the fault to be of the complex nature common to the "Ballan sunkland" (block C). The scarp here is generally lower; basalt in most cases covers the slope, and occurs both upon the upper and lower blocks. It is suggested (Fig. 7b) that the basalt sheet must have undergone fracture slowly, and have thus clung along the slope, and so remained. This is the portion of the scarp most difficult to read.

Where the glacial sandstones of the southern part of Bald Hill remain on the up-throw side of the fault (see Fig. 10), they show excellent exposures in plan and section of these beds, with a steep dip easterly towards the down-throw side of the Rowsley Fault. This fact, considered in conjunction with the already mentioned tilting of the tertiary series (ordinarily level-bedded), suggests that where the Rowsley Fault intersected the younger, more varied, less compacted, and more level-bedded rocks of the "Ballan sunkland," it partook more of the nature of a monocline. This is in sharp contrast to the abrupt break that marks the fault where it cuts through the harder folded Ordovician slates and sandstones.

North of Bacchus Marsh, the great valleys of the Lerderderg and the Korkuperrimul, with their thick alluvial terraces, obliterate the actual fault, which runs about a mile up the Korkuperrimul and then passes to the eastward of Bald Hill, continuing as the easttern boundary of the Lerderderg ranges. Near the point where the Lerderderg emerges from the Ranges, a fault coming from the northwest cuts across the scarp, and to the north of that we once more get a great resistant block of high Ordovician (Lerderderg Ranges) to the west, with less elevated Ordovician, glacials and tertiaries to the east. Thence the country is very difficult of access, and while the fault probably continues and dies out in the neighbourhood of Bullengarook, the evidence for this is wholly physiographic, and was not closely investigated.

We may conclude then that the Rowsley or Bacchus Marsh scarp is due to a fault, is most probably post-newer basaltic in age, is certainly so in part, has an average displacement of about 800 feet, and is at least thirty miles in length, trending about 15 to 20 degrees E. of north, and bounding the eastern faces of the Brisbane Ranges, the "Ballan Plateau," and the Lerderderg and Blackwood Ranges (see Fig. 5). Since the movement was probably one of uplift of the higher blocks (A, B and C), rather than a letdown of the lower block (E), it may be that it was contemporaneous with those uplifts that are classified as occurring in the "Kosciusko Epoch."

(ii.) *The Greendale Fault.*—The second important physiographic feature of the area is what we may refer to as the Greendale Scarp, forming the boundary between the blocks A and B (Fig. 2), and being the southern boundary of the great dissected block of Ordovician (Blackwood and Lerderderg Ranges), which stretches from the village of Greendale northward beyond the Main Divide of Victoria.

The existence of this fault was, the writer learns, suspected by Messrs. Hart and Baragwanath, but no references to it occur in the geological records of this State. In January, 1915, the University Geological Survey Party, under Professor Skeats, gave critical attention to the scarp, and clearly demonstrated its existence as a fault for some six miles, in the parish of Blackwood. The writer has since extended these observations to the west and the east, and has been permitted by Professor Skeats, and by Mr. Herman, Director of Geological Survey, to embody in this paper the evidence collected by the Survey Party referred to.

The whole of this area is known to be traversed by faults, running at all varieties of angles both across and with the strike. By far the most definite are the E.-W. series, as proved in the underground workings at Blackwood. W. H. Ferguson (ref. 18, pp. 5 and 26) records twelve "cross courses" (E.-W. faults), within a distance of three miles, in the Blackwood field. They are all vertical or moderately inclined, and in some instances the fissures are filled by dyke material, one being over 100 feet wide. The movement does not seem to have been very marked in most cases, and in many fractures there was no movement at all.

It would seem futile to endeavour to approximate an age for such faults and fractures as a whole, seeing that these lower Ordovician rocks have been the sufferers of every thrust and screw and crush to which this part of the lithosphere has been subjected since those lower palaeozoic times. There can be no doubt that the fractures and faults had their origin at many and various times, and that along any one ancient fracture line, movements may have occurred at every period of diastrophism since then.

There is a peculiar and interesting generalization which has been put forward concerning several areas of Victoria, viz. :—

(1) N.-S. dykes are acid.

(2) E.-W. dykes are basic.

Accepting as part of our creed that the devonian was par excellence the period of activity of acid magmas, and the tertiary as the chief period of the uprising of basic material, there would seem to be appreciable a further generalization to the effect that the E.-W. fractures were largely post-devonian, and the N.-S. fractures largely pre-carboniferous in origin. Many other factors and many other areas will need to be investigated before any generalization of value can be arrived at, but in a section dealing with the age of faults the idea was thought worthy of mention.

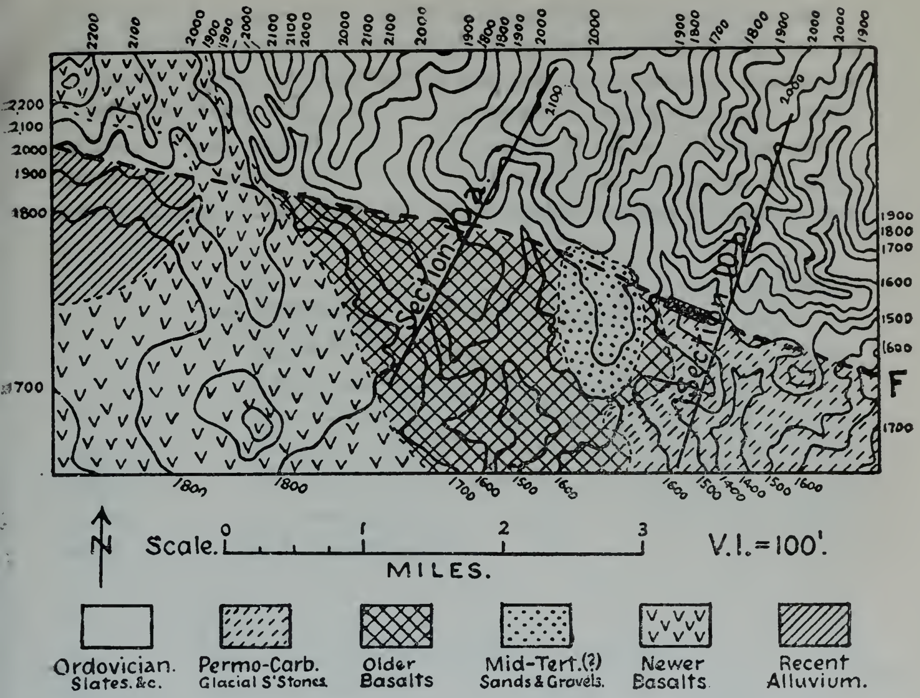


Fig. 8.—Plan of portion of the Greendale scarp, extending from Larkin's or Bald Hill in the west to beyond Greendale, showing 100-foot contours and general geology. The lines of the sections shown in Figure 9 are indicated. F — Fault.

The total length of the Greendale scarp is about eighteen miles. Fig. 8, with 100 feet contours taken from the maps of the Military Survey, shows also the geology of a large portion of this scarp. The evidence both physiographic and geological, is closely parallel to that of the Rowsley Fault. There is a varied area of hill, valley, and plain on the lower block B (referred to also as the Ballan sunkland), of an average elevation of 1500 feet. North of the scarp the average elevation is over 2000 feet; the transition from the lower to the higher level is usually abrupt, as shown in the sections which will be referred to. The scarp runs generally a few degrees south of east, turning to south-east beyond Mt. Blackwood. The line of the scarp is not straight, but this is quite in accord with the general characteristics of faults. As stated by Professor W. M. Davis (ref. 16):—"The fault may be nearly a plane or a conspicuously curved surface, but from all that is known of faults, it cannot possess sharp or exaggerated irregularities such as are seen in the septa of an ammonite."

Geologically, the evidence of the scarp being due to a fault may be best indicated by reference to three critical sections. Since these are drawn to scale, as in the case of those illustrating the Rowsley Fault, they also present important physiographic corroboration.

Immediately north of Greendale, where Dale's Creek emerges from its gorge in the higher Ordovician block, there is an excellent geological section indicated in the creek bed. This is shown

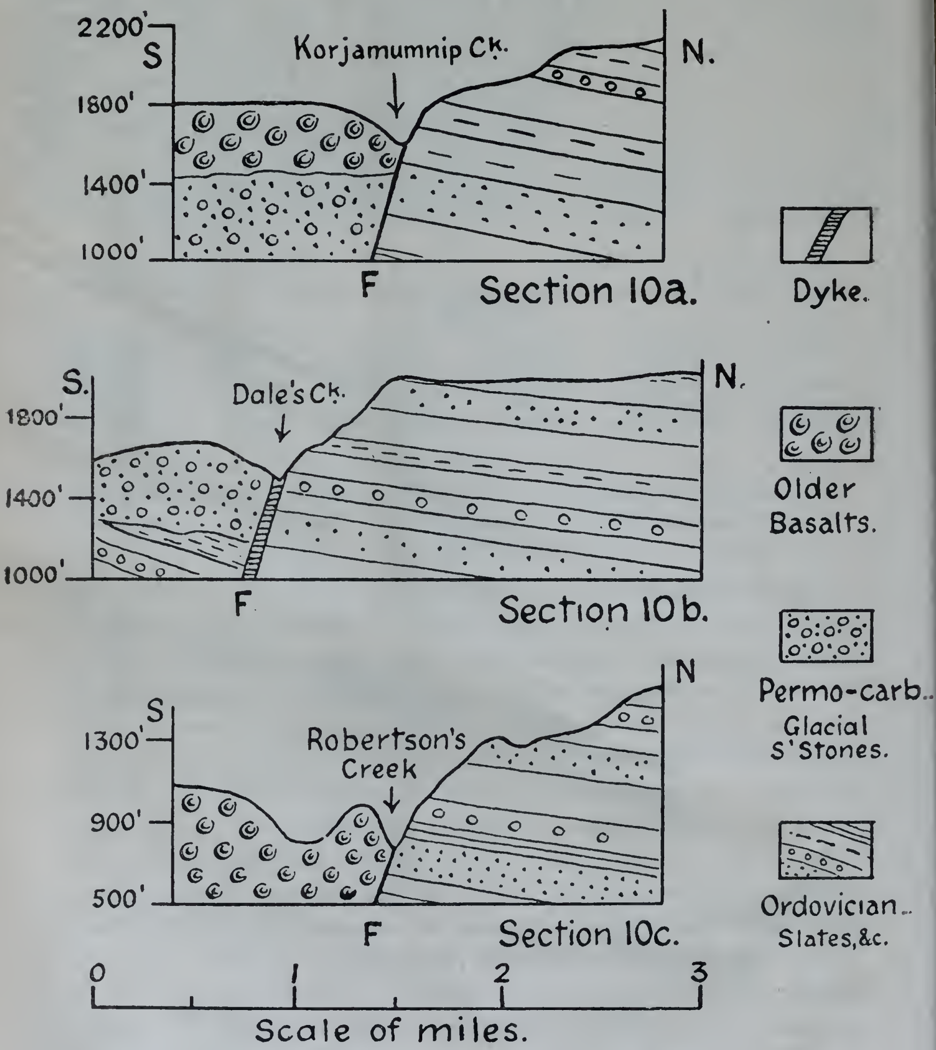


Fig. 9. Sections across the Greendale Scarp, along the lines shown in Fig. 8 (a and b), and Fig. 6 (c), showing geology and relief. A dyke marks the fault line in Section b.

by Fig. 9 (b). To the north rise the high Ordovician ranges, and in the creek-bed the upturned edges of these hard Ordovician slates are cut off sharply by a large east-west dyke. Immediately south of this dyke, the glacial (permo-carboniferous) sandstones occur. In a quarry a few hundred yards further south the same series is seen to be tilted to the north-west, and thus they must be butting directly against the Ordovician, a fact only capable of explanation by assuming a fault of a fairly extensive throw, probably 1000 feet. To the east of this point, small residual ridges, butting against the base of the Ordovician scarp, were dug into, and proved likewise to be Permo-carboniferous.

Further west, where the Korjamumnip Creek turns east for a short distance along the base of the scarp, we get the section shown in Fig. 9 (a). Here older basalt, undoubtedly resting on glacial sandstones, has been let down against the Ordovician. A visit to this point in the field provides excellent "fault evidence," both geological and physiographical. One stands on a low area of decomposed older basalt, cut off sharply along its northern boundary by Ordovician rocks; the latter are cut clean across the strike, and now rise above the observer in steep triangular-faced spurs, rock-strewn, and clothed with timber and bracken. Thick deposits of "scarp-base alluvials" lie on the older basalt a little to the east, and on the west the effect of the fault is further seen in the deflection of the creeks.

Further west, a tongue of newer volcanic passes, undisturbed, across the fault line; a series of bores put through this flow close to the line of the scarp gave the following results (ref. 40):—The newer volcanic, was proved by the first two bores recorded to be somewhat less than 200 feet deep, and of course underlain by river gravels. No. 3 bore, however, passed through 757 feet of basaltic rock without reaching bottom; either the older volcanics are developed to a great thickness close against the scarp, or else the bore came upon the wide dyke (referred to above) which is known to mark the boundary of the scarp for some distance; in either case the bore provides good confirmatory evidence in favour of a fault.

Further still to the west, the scarp may be clearly seen, but the development of newer-basalt flows on an extensive scale somewhat complicates matters. While it is quite possible that permo-carboniferous occurs on the flat ground south of Frichot's house, this has not been proved. The general higher Ordovician, however, continues on past the south of Bald or Larkin's Hill, and then on to the northward of Egan's Hill. It is very significant that no tertiaries or glacial deposits occur north of the scarp line in this part of the State, but such are found quite common (many of them unmapped) to the south of that line. The down-throw of the fault in its western part has probably been much less than at Greendale. Here, too, the fault passes away into the upper Moorabool area, and as the writer found it necessary to restrict detailed work to the prescribed area, further work to the west of Egan's Hill was not done.

In many places remarkably coarse conglomerates and gravels, 40-60 feet in depth, are piled up close against the scarp, notably so at Garibaldi Hill and Shuter's Hill, Greendale. They are much more dissected than the alluvial apron which lies along the base of the Rowsley scarp, and point to the greater age of the Greendale scarp. They are no doubt relics of the early deposits along the steep scarp face. The two deposits specially referred to suggest "fan deltas" in their shape, and in the extreme coarseness of the boulders close to the scarp.

Eastward from Shuter's Hill, the lower side of the scarp is of Ordovician slates similar to those of the higher block, but there is still a marked difference between the physiography above and below the "fault line." Blocks of fault conglomerate are strewn on the slopes here, and the wide valleys below the fault grade into the steeper-sided ones to the north. They remain, however, sufficiently distinct to enable the line to be followed.

Coming to Mt. Blackwood, we find that dominant hill to be a cinder cone perched on the uplifted block., near the edge; the contour of the flow proves that the valley down which it ran had a much steeper grade near the base of the hill, so that practically the whole of the lava flow ran down and debouched over the plain, that which remained above being mainly scoria. The exact line of the fault is here less clearly defined, but it is assumed that the remarkably steep descent of about 400 feet, shown in the present contour of the lava flow (Fig. 21), marks the point where the fault line crosses this area. Beyond this, we find the fault more clearly defined, stratigraphically, and trending south-east. It follows and then crosses the Korkuperrimul Creek, and we have once more glacial, older volcanic, and tertiaries at a much lower level than the Ordovician; where noted in the field the junction was abrupt and almost straight. David (ref. 13) refers to great differences (nearly 800 feet) in the levels of the known glacial pavements here. It is accepted that the glaciers moved northwards, about 12° E., and yet the Professor mentions that the base of the glacials lies at 660 feet in the Werribee Gorge, and at 1400 feet in the Lerderderg area (about 5-6 miles N.-N.E.). This anomaly is explained by the intervening fault.

The fault after crossing the Korkuperrimul, forms the northern boundary of the big let-down glacial block east of that river. For a few miles here, the writer is assuming the fault on the basis of previous geological and contour surveys, where the evidence is analogous to that of areas where the line was closely examined. Observations from viewpoints to the east and west confirm the assumption that the fault thence continues past Mr. Robertson's house, "Highlands." Here Robertson's Creek has followed the fault for some distance, providing excellent and unmistakable exposures. As we pass down this creek, we find always on the left the high block of Ordovician which forms the south-eastern triangular termination of the Lerderderg Ranges. (Fig. 6a.) To the south-west we invariably get younger beds, let down, and tilted at varying angles towards the south and south-east; these consist of the Bacchus Marsh tertiaries, thick flows of older volcanic, glacial sandstones and conglomerates, and also what appeared to be subglacial river gravels; all these deposits show signs of disturbance. The Greendale scarp then meets the Rowsley or Bacchus Marsh scarp. The consequence of this is of course that the northern continuation of the Rowsley fault has a much greater throw than further to the south.

Physiographically, in addition to the abrupt change of elevation mentioned and shown in diagrams, we have various features in the rivers which point to the truth of the explanation of the Greendale scarp as being due to a moderately rapid uplift of the northern block; it was considered more convenient to deal with such features when describing the rivers. As already detailed, conclusive fault evidence occurs abundantly in the field, much more telling than diagrams and descriptions. Still, the evidence so far put forward in this paper is sufficient to show positively that the scarp described marks a line of extensive faulting. In consideration of the fact that it was first definitely proved near the village of Greendale, it is called the "Greendale fault." For plan see b, Fig. 5.

To come now to the question of age, we find that, while in some cases the face of the scarp is remarkably well preserved, there is other physiographic evidence (such as the greatly dissected nature of the alluvial apron) which suggests that this scarp is much older than that of the Rowsley Fault.

There are points along the face of the Greendale scarp where the evidence would seem to favour a more recent age than that assigned in this paper, as far as the recession of the scarp face by erosion is concerned. Likewise there are places along the Bacchus Marsh scarp where erosion is so far advanced as to suggest a greater age than is here given. Many other similar anomalies were noted, pointing to the impossibility of making correct calculations as to relative age purely on the physiographic appearance of limited areas.

That the Greendale fault was post permo-carboniferous and post older-basaltic is clear from the geological plan (Fig. 8), and sections (Fig. 9 a, b and c),. There cannot be any doubt that subsequent to the fault some glacial and older basalt remained on the higher block, and have since been almost entirely destroyed. Scattered striated pebbles were found on the crests of the ranges, as were small patches of glacial conglomerate previously referred to. The writer also came across an area of scattered basaltic boulders marking the truncated neck of what was probably an older volcano; this was high up on the Ordovician peneplain to the north of Greendale and has been mapped.

The road that passed Mt. Steiglitz proceeds on to the north towards Blakeville along a tongue of basalt. This is undoubtedly newer volcanic, though coloured as older basalt in some geological maps. The depth and maturity of the valley so filled by basalt is abundant proof that the fault is much older than the newer volcanic flow which fills it. It may possibly be correlated in age with the first great period of uplift of New South Wales geologists (ref. 48), but is here plainly subsequent to the older basaltic lavas.

(iii.) *Minor Faults.*—Several other faults occur in the Werribee River area, but these were not so minutely examined as the two main ones already described. They will be dealt with as under :—

More extensive faults:
- a. Fault bounding the southern edge of Block D.
- b. Fault bounding the southern edge of the Ballan sunkland.
- c The Steiglitz Fault.

Less extensive faults:
- d. The Coimadai fault.
- e. The Bald Hill faults.
- f. Other small faults.

(a) Fault bounding the southern edge of block D (see e, Fig. 5). The evidence in this case is largely physiographic, since, as will be seen from the geological map, the higher Ordovician block is more dissected and largely covered by newer volcanic cones and flows, grading down to the lower basalt-covered Werribee plains (block E). Towards the west there are two large areas of glacial conglomerate on the down-throw side, but otherwise there are no geological distinctions between the two sides of the suggested fault, due largely to the extensive erosion and the covering of volcanic material.

Physiographically, we find this Gisborne block, whose elevation is much increased by such volcanic masses as Mts. Bullengarook and Gisborne, is really on the average much lower than Block A—the Blackwood and Lerderderg Ranges, and slopes downwards to the east. The wide east-flowing valley of the Gisborne Creek occupies the main part of the block, and this valley extends across to the Main Divide at Macedon. There is, however, a fairly sudden drop along a general east-west line, as may be noted when travelling up the Bullengarook road, at the point where the basalt flow is very narrow (see Fig. 22). The road from Coimadai to Toolern Vale runs along parallel to and somewhat south of the line believed by the writer to mark this fault. To the north are higher, severely-eroded, timbered ranges of folded lower Ordovician slates, quartzites, etc., but the lower area traversed by the road shows abundant gravelly deposits, some basalts, and a little permo-carboniferous, while the Ordovician here outcrops mainly in the creek beds.

On the main road from Gisborne to Melton we again find an extremely steep fall of over 400 feet in little more than a mile (Breakneck Hill). Further east, outside the area examined by the writer, there is a steep climb for the train after it leaves Sunbury for the north; this rise is mainly due to the erosive work done by Jackson's Creek.

The western part of the block, at the head of Pyrete and Djerriwarrh Creeks, is a very deeply dissected mass of folded Ordovician slates, etc. The exposures of these rocks become less extensive and less rugged as we go east, and volcanic rocks become more and more in evidence. To the south on the let-down block no Ordovician occurs, except at a very low level (about 600 feet) in the valleys of the Pyrete and Djerriwarrh creeks, as may be seen where the Melbourne road crosses those streams, or higher up near Coimadai. Between the lower and the higher Ordovician a fall of over 400 feet is distinctly noticeable. This difference of level rapidly decreases to the eastward.

The most convincing physiographic evidence is found in the grades of the rivers. The Pyrete, Djwerriwarrh and Toolern creeks flow south from the Gisborne highlands into the Werribee.

The grades of the Djerriwarrh, Toolern, Boggy and Condon's creeks have been carefully plotted in Plate XIIB. An inspection will show that they clearly tell a story of rivers rejuvenated in their upper reaches. The lower five miles or so of these streams show a gentle rise of 100 feet to the mile. At the point where other physiographic evidence suggests a fairly well-dissected scarp line, these streams rise 500 feet in a mile—a grade five times as steep as that below; thence to the top of the highlands the grade is less steep, giving us a line of the nature shown in Fig. 25. This is a quite similar line to that of the Lerderderg and Werribee, due to their rejuvenation by faulting (see also Plate XIIa.), as well as to that given by Chamberlin and Salisbury (ref. 10, p. 163) in their diagram to represent the grades of a partly rejuvenated stream.

The evidence presented, though not as complete as could be wished, owing to the reasons stated, is yet sufficient to enable us to map approximately the "Gisborne Fault,"—which here forms part of the northern boundary of the great Port Phillip sunkland. The fault has its greatest throw in the west, where the deeply-ravined Ordovician of the upper Pyrete creek, etc., occurs; the throw becomes much less as we proceed eastward. No date can be definitely stated, but the writer believes it to be probably of the same age as the Greendale fault.

(b) *Fault bounding Southern edge of the Ballan Sunkland.*

(See Fig. 5.) The very important sunkland of Port Phillip, and the less extensive but equally interesting one of Ballan, which will be dealt with in detail later, have already been referred to. These names are introduced at this point since it is felt to be the most convenient method of referring to those particular areas. In dealing with the southern edge of the Ballan sunkland, the writer is again describing a feature which extends for some distance out of his limited area. It has only been examined where it lies within the Werribee basin, and other evidence to the west is based on published geological maps and records.

Physiographically we have no evidence of this fault, except that the valleys immediately north of the fault, being in the much younger and softer beds of the let-down rocks, are much wider than those to the south. There is now no scarp present, as is indicated in the north south section (Fig. 13); this figure also shows, diagrammatically, the geology of the section. Spring Creek, a tributary of the Parwan, flows for part of its course along the boundary between the Ordovician and tertiary, i.e., along the fault line. Where investigated by the writer, this valley is steep and V-shaped, over 300 feet deep; on the right bank the high resistant slates, etc., of the Brisbane Ranges occur, truncated at right angles to their strike, while in the bed of the creek and high on the left bank, easily eroded tertiary beds ("leaf-beds") occur. These are capped by newer volcanic, which further west extends well over the fault line towards the south. Two streams—a southern tributary of Yaloak creek (flowing north), and the eastern Moorabool (flowing south)—cross the fault line, and might be expected to provide good sections. This is found to be the case, since the geological map of the parishes of Bungeeltap, etc., by Mr. E. J. Dunn (recently published) shows valuable confirmatory geological evidence of the fault.

In the Eastern Moorabool the steep valley sides change abruptly from the hard Ordovician to the soft tertiary sand and clay beds. The Yaloak creek tributary shows just as sudden a cutting off of these two formations, giving rise to the peculiar tributary, like an inverted T, shown in Fig. 37. Both junctions referred to are in an almost straight east-west line, and are also in line with the area on Spring creek, where the fault was first assumed by the writer. Mr. Dunn's map was kindly brought under my notice by Mr. Baragwanath. The writer has mentioned this evidence to Mr. T. S. Hart, and he suggests the same fault may continue to the west and form the southern wall of the very deep basin of the Lal Lal brown coal beds (ref. 24). The pre-existence of this fault junction may have influenced the Rowsley fault, causing it to change direction slightly at the point of intersection.

This fault, which may be called the Spring Creek Fault, is therefore put forward as the explanation of the very significant structural line separating the barren and unproductive Brisbane Ranges from the rich and geologically varied area of the Ballan sunkland to the north. It is perhaps of the same age as the Greendale fault, runs nearly east-west, and has a considerable down-throw to the north.

(c.) *The Steiglitz Fault.*—Mention of the Steiglitz fault is included here, in order to have as complete a record as possible of the chief faults within this area. The writer has, unfortunately, been unable to follow this line; he has, however, examined the country to the northward, at Steiglitz, both geologically and physiographically, as he has also done to the south, in the Maude and Lethbridge areas.

The contrast between the two parts visited, when compared with other similar areas which have been closely examined, strongly suggested an important break between the two, with a let-down to the south. This evidence also fitted in with the fact that from nearly every distant view, a peculiar break was noted in the level summit line of the Brisbane Ranges. All of this was of course insufficient evidence on which to assume a fault. The writer has, however, been delighted to discover that an extensive fault has been proved to run through south of Steiglitz; it has been located and investigated by Mr. W. H. Ferguson, of the Victorian Geological Survey, and the evidence is of a most striking and complete stratigraphical nature. Mr. Ferguson's report is, unfortunately, so far unpublished, but permission to include the foregoing statement in this paper has been kindly granted by the Mines Department.

(d) *Coimadai Fault.*—(See d Fig. 5.) This fault is probably of the same age as that at Greendale. The fault line is short, about five or six miles, and runs east-west with a down-throw to the south. The evidence is both physiographic and geological. The ancient "Bullengarook creek," now filled by the Bullengarook lava stream (ref. 42), flowed across this fault.

The country to the north is much higher than to the south. On the western side of the Bullengarook lava flow, Back creek flows eastward along the fault. On the left bank (north) the Ordovician rises steeply, and on the right bank there is a large area of glacial conglomerate. The boundary line, as mapped by Officer and Hogg (ref. 43) is almost straight, but it does not appear to be referred to by these writers as a fault. They apparently regarded the east-west Ordovician escarpment as a pre-permo-carboniferous feature—surely a physiographic impossibility, since the great mass of permo-carboniferous glacial rocks, that now lie at a much lower level near the base of the scarp, are accepted as relics of glaciers that flowed in a northerly direction. Hart (ref. 22, p. 257) records his belief that this line would be found to mark a fault.

On the east of the Bullengarook basalt tongue, the limestones, tertiary sands, and glacial beds of Coimadai are on the let-down side of the fault, while the steep "pinch" on the road that runs north from Coimadai to "The Basin" is really ascending this fault scarp. It is quite likely that differential erosion has accentuated the scarp just here, but the geological relations are conclusive.

(e) *The Bald Hill Faults.*—These faults are best seen in the field in summer, when the grass is dry, and the soil differences are most apparent. They occur at Bald Hill, north-west of Bacchus Marsh, and form the boundary between the older basalt (black clayey soil) and the glacial sandstones (light sandy soil).

It was thought advisable to closely investigate the faulting of this area, as typical of the small faults that are believed to abound throughout the whole of the Ballan Sunkland. Both the geology and physiography proved to be of much interest. Fig. 10 shows the particular area in some detail, with 50 foot contours. Bald Hill itself forms the central portion of this plan, running from the north to the south. The steep bounding valley on the western side is that of the Korkuperrimul Creek, while the wider valley, partly shown on the east, is that of the Lerderderg River. At least four faults occur in this small area, and their influence is very clear both in the geology and the topography. These faults are marked by the letters A, B, C, and D. The fault marked A has been already described as part of the Greendale Fault; B is portion of the Rowsley Fault; C and D are two smaller faults that we may call the "Ball Hill Faults."

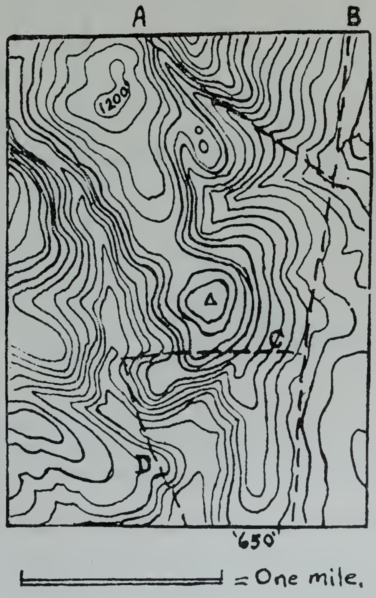


Fig. 10.—Contour plan of Bald Hill, near Bacchus Marsh. Fifty feet vertical intervals. A, B, C, D indicate faults referred to in Section VIIIb.

Geologically, there faults form almost exact boundaries. For instance, the triangular patch in the north, bounded by faults A and B, is Ordovician—portion of the high Lerderderg Ranges.

The low country, with gentler slopes east of Fault B, is of tertiary and terrace material, with a little low-level glacial in the northern part. The southern and lower part of Bald Hill, enclosed by faults D, C, and part of B, is a block of permo-carboniferous glacial sandstones, with a distinct easterly dip. The remaining area in the plan, the western portion, consists of high steep hills of older basalts, dipping down under tertiary leaf beds to the south. Not only have we this distinct geological evidence, but three of the four faults in this small area have been selected as stream valleys. The field evidence for fault C is good; although no section is to be seen, the junction between the glacial sandstones and the older basalt is a straight line that may be traced over the hill, for about a mile in length and at least 300 feet in vertical height. Just before reaching the bed of the Korkuperrimul, it is intersected by another fault, D, running south-easterly.

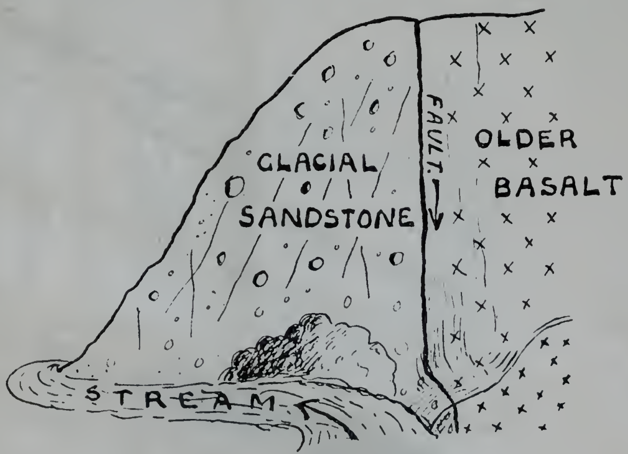


Fig. 11—Fault section exposed in cliff on right bank of the Korkuperrimul Creek, near the letter D. Fig. 10. The older basalts are let down against Permo-carboniferous glacial rocks.

The fault marked C probably continues westward, but since it there cuts through older basalt alone, it is not easy to follow. Where it would cross the Korkuperrimul creek, there is some evidence of its continuation through the older basalts on the right bank. The Korkuperrimul does not quite follow the fault line, D, but lies more in the older basalts of the western side, and in its bends provides conclusive sections of this fault. Going down the creek, we find a steep cliff of glacial on the left bank where the Korkuperrimul has taken a sweep in that direction; at both ends of this cliff there is evidence of the fault D, older basalt lying against the glacial with an almost vertical junction; the section more upstream is soil-covered, but quite clear, the lower one is bare, and shows the decomposed basalt and glacial sandstones with a steep line of contact.

Continuing this line down-stream, however, an excellent section is found. Where the fault D crosses the Korkuperrimul, just above the letter D in Fig. 10, a cliff section, 20-30 feet high, shows the junction as depicted in Fig. 11. This last-mentioned fault increases in throw towards the south; at the north end a small cliff of glacial, with overlying basalt, occurs in the creek on the left bank.

(f) *Other small Faults.*—The preceding faults comprise all those of which the evidence is held to be satisfactory. As already mentioned, it seems undoubted that certain areas, especially the Ballan sunkland, structurally consist of a mosaic of faulted blocks. Mr. Baragwanath, who is at present engaged in a geological survey of the parish of Gorong, etc., has a good deal of evidence pointing in the same direction; much of this the writer has had the pleasure of examining with him in the field. The evidence for the faults is mainly provided by the older basalt and glacial beds, and many of them are suspected to be of the nature of the Bald Hill Fault.

(iv.) *Previously demonstrated Faults.*—These are dealt with as:

(a) Selwyn's Fault and others.
(b) Faults near Geelong.

(a) *Selwyn's Fault.*—This very extensive and dominant fault (see h, Fig. 5, for plan), some fifty miles long, and with its chief down-throw (over 1700 feet) to the west, was first mentioned by Selwyn in 1857 (ref. 27), and has been frequently referred to since. In a map of Australia's Tectonic features (ref. 12) a north-south fault is shown cutting through Port Phillip, and hading west; it is labelled "Sorrento fault," and may refer to the one now being discussed.

What is believed to be the northern continuation of this fault has more recently been mapped by Morris (ref. 38), who states that the down-throw of this fault (referred to by him as the Montrose fault) is to the eastward, in the neighbourhood of the Dandenongs; he therefore regards the whole fault as "pivotal." The same writer has also published accounts of the Olinda fault (E.-W.), in the Lilydale area, and the Evelyn fault, hading east and parallel to the Montrose fault, about two miles further east.

The Croydon sunkland worked out on physiographic evidence by Jutson (ref. 33) has its locality suggested by a line, K, in the north-eastern corner of Fig 5. Regarding Selwyn's fault, it may be mentioned, as of physiographic interest, that where the line cuts across the granite mass of Arthur's Seat, it has left a straight and clean-cut boundary for some two miles, and in the resistant granite this face has been wonderfully well preserved (see Military Survey's Sorrento Sheet).

Mr. Chapman's evidence (ref. 8) from the famous Sorrento bore, shows a down-throw to the west of over 1700 feet. In a letter regarding the palaeontological evidence of the Sorrento bore (on the down-throw side of Selwyn's fault), Mr. Chapman writes:—"I think that here we have perhaps the oldest piece of evidence of Kainozoic faulting, which may date back to the Oligocene, for in no other way can I see an explanation of the great thickness of sediments of Balcombian age in the Sorrento bore, which maintains a fairly equable bathymetric aspect throughout. And here the movement probably continued till Pleistocene times, and the area may be subject to fits of weakness and collapse even at the present day." The fault is shown in section, Fig. 12, as the eastern boundary of the Port Phillip sunkland.

(b) *Faults near Geelong.*—Dr. Hall (ref. 28) mentions an east-west fault bounding the northern face of the soft Jurassic mudstones of the Barrabool Hills (see g, Fig. 5). At right angles to this fault there are apparently two other short ones, with a high ridge (horst) between. Dr. Summers and others have made investigations concerning these faults, and the evidence is generally accepted as conclusive; nothing as far as known to the writer has been published concerning them (except ref. 28). That to the west is commonly referred to as the Orphanage hill fault, and runs through near the cement works, meeting the Barrabool hills fault about Queen's Park, and forming the triangular "let-down" basalt plain between the junction of the Barwon and the Moorabool. The eastern one (Fig. 5) is believed to be marked by a low scarp that runs nearly north-south through Lovely Banks. This line is very clearly delineated on Quarter Sheets 19 S.E., 24 N.E., and 24 S.E., and is about fifteen miles long. (See also ref. 46.)

(v.) *Suggested Fault.*—We may be permitted to leave the domain of more or less demonstrated fact, in order to indicate a line that suggests itself as being a significant structural feature in the physiographic evolution of this area. It will be referred to as the Doran-Egerton line.

The writer, travelling a good deal over the country south of Ballarat, has been struck by the dominance of north-south Ordovician ridges rising above the newer basalt sheet. The important and isolated Ordovician heights of Mt. Doran, Mt. Egerton, and Haydon's Hill—giving a line sixteen miles long running a few degrees east of north, has already suggested itself to various observers as a relic of the eastern up-tilted edge of a fault block. Thy physiographic evidence seen in frequent cross-country traverses in that area, backed by the contours shown in the field notes of the Commonwealth Military Survey, point towards this line marking a fault, parallel with those of the western highlands, as demonstrated by T. S. Hart (ref. 22).

(vi.) *The Sunklands.*—Little remains to be said concerning the great relatively sunken blocks of the Werribee area, which have already been frequently referred to. They are :—

(a) The Port Phillip Sunkland.

(b) The Ballan Sunkland.

(a) *The Port Phillip Sunkland.*—This has been referred to mainly as block E, though it of course extends beyond that block, embracing Port Phillip Bay. The northern limits of this area have not been investigated, except along the base of the Gisborne highlands, but the east and west limits are the Rowsley and the Selwyn Faults respectively. This relatively sunken block has given Victoria her two chief harbours, the sites of her early settlements, and of the capital city. The known limits are set out in plan in Fig. 5 and a section drawn from the 50 foot contours of the Military Survey is shown in Fig. 12, with the geological structure also marked in. The economic aspects have been already referred to under the heading of general description of the area.

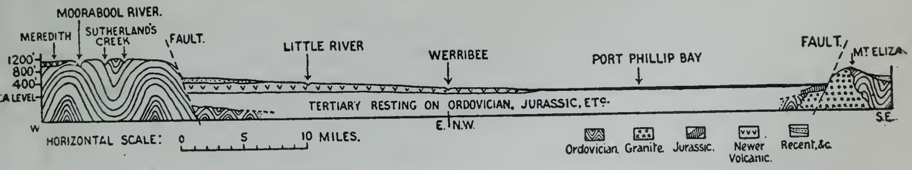


Fig. 12.—Section across the Port Phillip Sunkland, from Meredith to Mount Eliza, showing geology and relief.

The section (Fig. 12) is drawn from Meredith, east to the town of Werribee, and then south-easterly to Mt. Eliza. It will be seen that the sunken portion slopes gently from west to east, the eastern portion, Port Phillip, being below sea level. The depths of the

Bay were slightly exaggerated in the figure in order to show that feature. The eastern boundary, Selwyn's fault, has been proved to be of greater age than the western boundary, the Rowsley scarp. Probably later movements have taken place on the east (ref. 8), and earlier ones on the west, although the latter have so far not been demonstrated.

(b) *The Ballan Sunkland.*—This area has also been previously described, as regards its economic and other aspects, having been referred to as block B. It is bounded on the north by the Greendale fault, and by a fault of probably similar age on the south, shown in Fig. 5. On the west the suggested boundary is the Doran-Egerton line, beyond which no glacial nor older basalt is preserved as far as known. In the east, the Ballan sunkland is bounded by the Rowsley fault, and stands higher than the Werribee plains; it may be known alternatively as the Ballan Plateau, a distinct geological unit in the larger Ballarat Plateau (refs. 20, 21). A

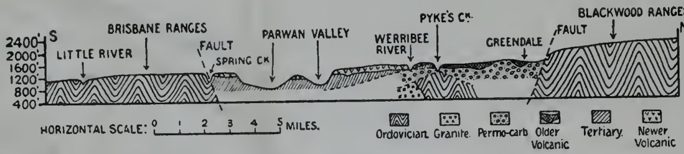


Fig. 13.—Section across the Ballan Sunkland, showing geology and relief. Note the complex structure of the let-down block. In these sections the geology is necessarily to some extent diagrammatic.

section drawn to scale from the Military Survey maps (50 foot contours), with the geological formations diagrammatically suggested is shown in Fig. 13.

(vii.) *Final conclusions as to age.*—We see then that there are here two dominant and undoubted faults with fairly clear age relationships, and these should prove important factors in arriving at the precise period of uplift of our highlands, a matter which we have already discussed. The writer is led to the conclusion that—

(1) the peneplanation was completed about the time of the Older Volcanic period.

(2) Differential uplift took place subsequently with extensive faulting.

(3) Dissection, etc., continued up to the Newer Volcanic period, closely subsequent to which a further series of uplifts occurred, slowly bringing the main highlands of Victoria to their present general levels.

(4) The dissection already begun was then continued, except where interfered with by the newer basalt flows. In the latter cases new stream valleys were carved out, as detailed in a later section.

An important and interesting corroboration of portion of these conclusions, reached independently by Mr. Chapman (ref. 8, pp. 401-407), has been recently published by that gentleman. His evidence is purely stratigraphical, based on a knowledge of richly fossiliferous beds, and connected with the first-proved extensive fault in this State—that known as Selwyn's fault. A differential movement of 1700 feet is referred to, and a positive elevation of the up-throw side is believed to have taken place about the time referred to in this paper as the Older Volcanic period. This is approximately the age given for the Greendale, Spring Creek and other leading faults in the Werribee area.

While the two great uplifts in the Werribee area—the Greendale uplift, and the Bacchus Marsh uplift—are referred to certain ages, it is not assumed that the fractures themselves really originated then. Rather is it possible that extensive movement had taken place along them prior to that long "still-stand" that produced our peneplain. It is generally accepted that great faults are probably not developed by a single movement, but by repeated displacements, separated maybe by long intervals of time (Salisbury "Physiography."). Professor David (ref. 12) shows, in a generalized section, the Victorian permo-carboniferous preserved by assumed faults, and such movements must be accepted to some extent to account for the preservation of such soft and friable rocks during planation. To come to a much later date, there are at the Ballarat School of Mines interesting and reliable records of an abrupt lift of 23 feet met with in an auriferous sub-basaltic deep lead, near Smeaton, compiled by the Manager of the Mine concerned, Mr. J. McKenna, 1882; similar records exist from neighbouring mines. Again, there seems no doubt that movement is still proceeding at an extremely gentle rate. Interesting positive evidence of this has been noted by the writer in the New Normanby mine, at Ballarat, north west of the Werribee River area. In the western cross--cut at the 1500 foot level of that mine, there were some half-dozen small faults noticeable, within a few yards, totalling a downward throw of over 8 inches. This movement occurred in less than two years. At the time it was noticed, this was the deepest level on the field, so that the movement must have been of a general nature. The faults here ran along a north-south line.

These were pointed out to the writer, and the particulars kindly supplied by Mr. W. Baragwanath, of the Victorian Geological Survey.

East-west movement has also been reported as taking place in recent years. Mr. W. Bradford, of Ballarat, tells of a case of a shift of about one-foot laterally (E.-W.) in a drive in the Star of the East mine, Ballarat, at the 1300 foot level, subsequent to putting in the drive; the particulars of this movement were communicated by him to the Mines Department. Taylor (ref. 52) regards the great N.-S. Lake George fault scarp of New South Wales as being formed 20-30,000 years ago.

J. T. Jutson, in a paper on the older basalts of Greensborough and Kangaroo Grounds, suggests that some of the Victorian basalts are intermediate in age between the older and newer basalts. As far as our present knowledge goes, this series is much less important and extensive than either of those of the two other periods. In this paper the two chief periods—"older basaltic" and "newer basaltic"—are used as benchmarks of time, with certain cautions already laid down, and the intermediate series is not referred to. As investigations proceed into the many obscure

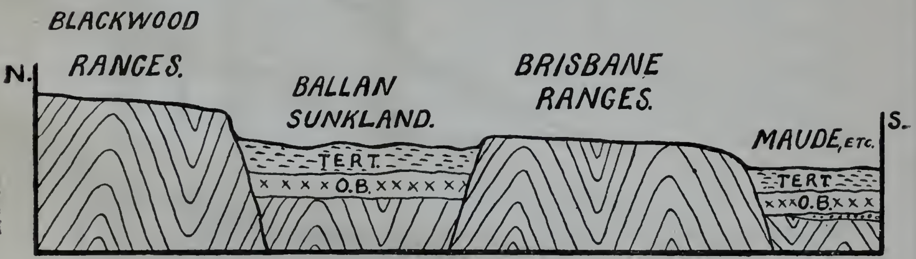


Fig. 14.—Diagram to illustrate the probable relationship of the Older Basalts (O.B.) and tertiaries (Tert.) of the Ballan Sunkland and of Maude to the neighbouring ordovician (folded) blocks.

points of our Victorian geology, demonstrated physiographic facts will no doubt aid the petrologist and the palaeontologist in the elucidation of the problem of the exact distribution of these three basaltic series and their true places in the time-record. For instance, the known structural features of the country from the Divide to the "Great Valley of Victoria," through the Parwan Valley and Maude, strongly suggest that the older basalts and the overlying tertiary beds of the Bacchus Marsh area may be correlated in time with those of Maude, although the former are freshwater and the latter partly marine. Both series are preserved in troughs that we may reasonably believe to have been formed at the same period. The idea is diagrammatically illustrated in Fig. 14.

(c) *The Newer Volcanic Sheet and its Effects.*

Fig. 15 has been drawn to show the extent to which the newer basalt has affected the physiographic features of this area. This map of course shows the minimum extent of the basaltic sheet—it has in many parts been hidden by later alluvial deposits, while in other places it has been eroded away. With the exception of the high block of the Blackwood and Lerderderg Ranges, with a small portion of the Gisborne highlands, and most of the Brisbane Ranges, the basalt sheet must have practically covered the whole of the area. The Blackwood Ranges seem to have escaped on account of their being then much higher than the general low even surface of the remainder of the area. Even so we have various small areas of lava on this block, with evidence that these patches were once more extensive—as at South Bullarto, Wuid Kruirk, Mt. Wilson, Blakeville, Upper Werribee, Green Hills and Mt. Blackwood itself.

It will be seen that the task of deciphering the buried physiography is a very difficult one. The well-known figure of speech comparing such a task with the deciphering of a palimpsest is particularly applicable. The old stream courses have been almost entirely obliterated, and only at rare intervals do we discover relics, mainly where the post-basaltic streams have cut through the volcanic sheet, exposing something of the rocks below. To use the words of one geological writer (ref. 32) :—"Like a moss-grown inscription upon a slab of marble, though veiled it may be deciphered." The writer must confess that many of the problems concerning the buried rivers remain unread, but some important evidence has been collected.

It may be first stated that the surface before the newer basalt flows was of low relief, with one or two exceptions. The Greendale and probably the Gisborne scarps were in existence, as were the wide valleys of the Lerderderg and Gisborne creek. One or two monadnocks, as the You Yangs and the much lower granitic portion of the Anakies stood above the general level, as also did a low rounded dome of Ordovician slates and granite in the neighbourhood of our present Werribee gorge. Elsewhere the relief was not marked, since apparently blocks B, C, and E must have been almost at sea level. In the raised blocks A and D, as mentioned, the relief was much more distinct, the dissection of the lifted peneplain in those areas having by this time been well started. Mr. Charles C.

Brittlebank (ref. 6) mentions old channels filled by newer basalts, 170-350 feet deep. That gentleman has kindly taken me to see each of these various interesting sections of old river valleys that he has discovered, in the neighbourhood of "Dunbar," Myrniong.

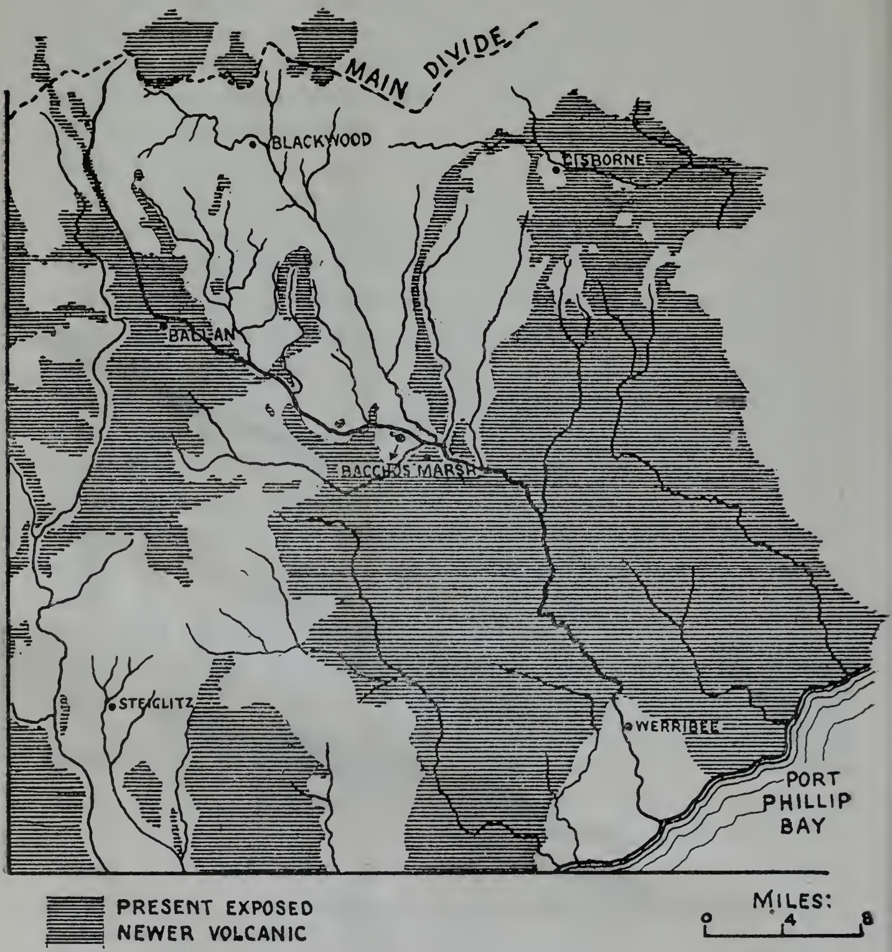


Fig. 15.—Map showing the extent of the Newer Basalt lava flows, as at present exposed The basalts were originally more extensive, but in places have been eroded away, and in the other places obscured by deposition of alluvial materials (Section VIII c).

Added to these are others found by the writer, and altogether they enable an interesting part of the ancient river courses to be well mapped out. This will be dealt with under the heading of buried rivers.

While we see that over an area of low relief the basalt spread as a great level sheet, filling the valleys and covering the low dividing ridges, this was not the case in the higher country where deeper valleys existed. In at least five places we have the volcanoes originating in higher areas, and sending their lava flows as long tongues down the existing valleys.

In some cases this infilling resistant tongue caused the formation of two new streams, one on either side of the basalt flow. Such streams run closely parallel for good distances, and are very common in many parts of Victoria—e.g., Goodman's and Pyrete creeks, upper parts of Myrniong and Korkuperrimul creeks, etc., etc. It is so characteristic a feature that for the purposes of our

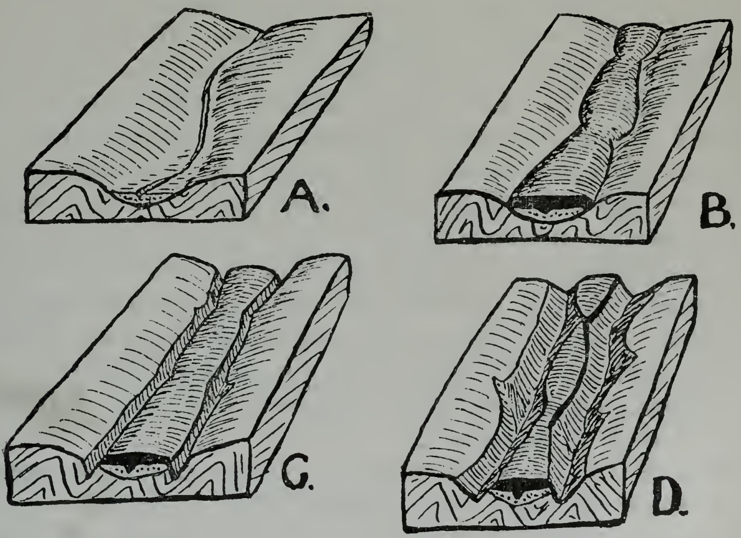


Fig. 16.—Diagrams to illustrate the origin and progressive erosion of "Twin Streams." In connection with the Newer Basalt flows in Victoria, such erosion has rarely advanced beyond the stage shown in D.

local geography, it might be well if a special name were used for descriptive purposes. On account of the similarity of their nature, and the contemporaneity of their origin, it is suggested they be called "twin streams" (see Fig. 16a, b, c. d).

The basaltic tongues referred to are:—

i. From Leonard's Hill and other points thereabouts, long tongues came southward down the valley of the upper Werribee, through Korweinguboora, etc. (It is possible that some "older basalts" occur here also.)

ii. From Bald or Larkin's Hill, and from a point near Blakeville, a tongue came down in an old stream, crossing the Greendale fault north of Mt. Steiglitz.

iii. From Greenhills, a tongue ran down what is called Greenhills Creek, a small tributary of the Korjamumnip. This flow did not reach to the edge of the scarp.

iv. From Mt. Blackwood, a tongue came down an old river that flowed midway between the present Myrniong and Korkuperrimul—referred to later as the "ancient Myrniong" (see Fig. 21).

v. From Mt. Bullengarook a long tongue came down between what is now Goodman's and Pyrete (or Coimadai) creeks. This has been previously described (ref. 43) as the "ancient Bullengarook" river. (See Fig. 22.)

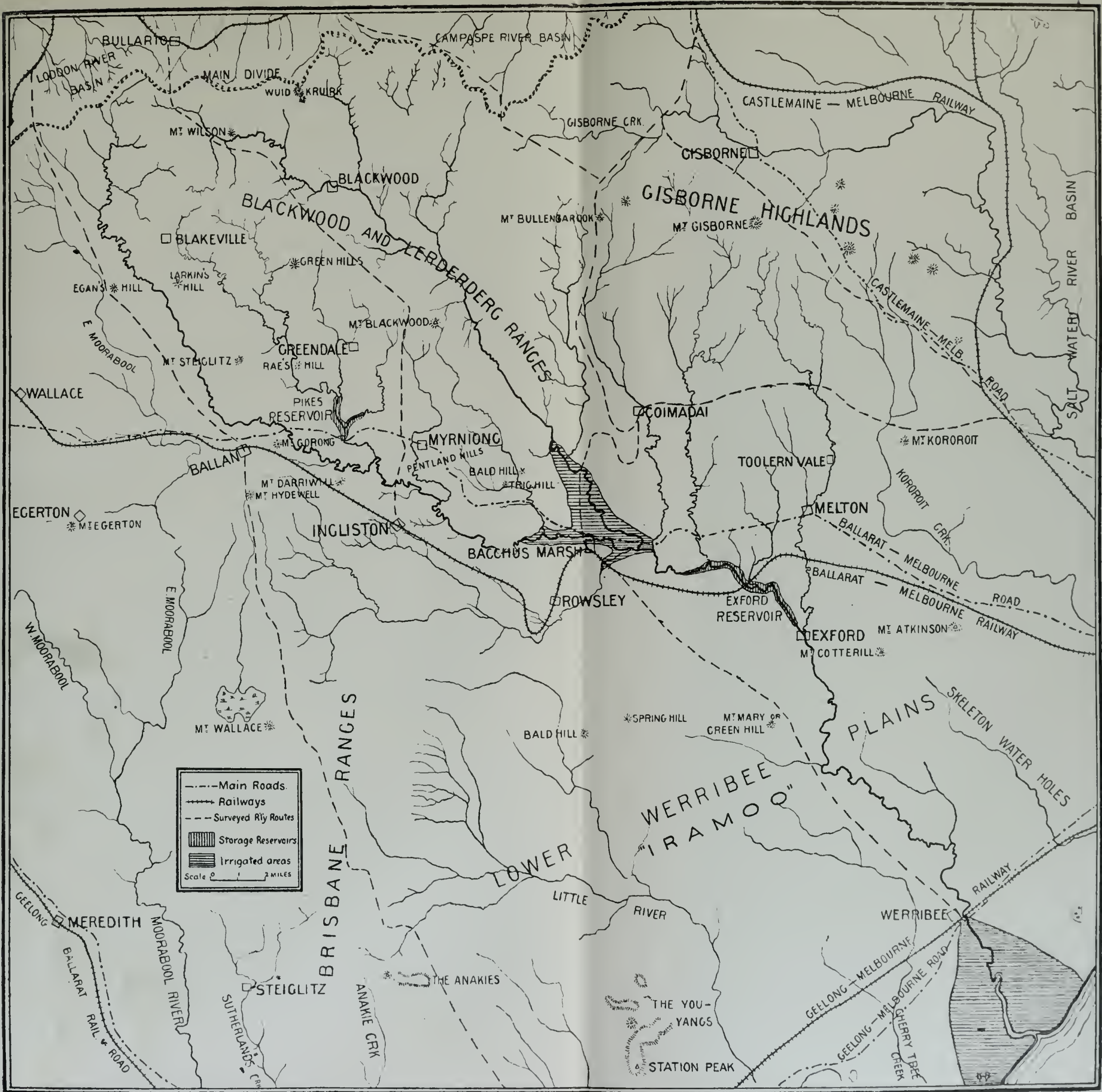
The general effect, therefore, especially on the less elevated areas, was obliteration. A new series of streams was formed on this new surface, twin streams were originated on the higher surfaces, old and uninterrupted streams, such as the Upper Lerderderg, were forced to find new courses in their lower parts. All these streams were rejuvenated, since a basaltic sheet is quite analogous in effect to an uplift movement. Closely following, or in the later stages of, this volcanic period, however, there was a great general uplift, in addition, of all the blocks in the area except the Lower Werribee plains (block E). The streams were thus doubly rejuvenated, and were given a scarp from which to commence their gorge-cutting and general work of denudation.

Even on the lower plains there was a certain amount of rejuvenation, due to the basalt sheet; thus we find the Werribee and other streams now flowing in narrow young gorges averaging 100 feet in depth. (Fig. 27.) It was above the scarp, however, that the most severe action took place, and there we have the deeper gorges of the Upper Little River, the Parwan, the Werribee, the Lerderderg, etc. This gives us, broadly speaking, the effect of the newer basaltic eruptions. Economically, of course, the effect of the basalt flows is very great.

IX.—Detailed Account of the Physiography.

(a) *Ranges and Hills.*

(i.) *The Main Divide.*—As will be seen from Plate XI., the main Divide of Victoria does not enter very largely into the area under discussion. The head waters of the Werribee and of the Ler-



General Map of the Werribee River area, showing the chief centres of population, with main roads and railways, other surveyed railway routes, streams, etc. The main localities mentioned in the paper are shown in this map.

derderg have their rise there, as also have many other Lerderderg tributaries, such as Split Tree, Frenchman's, Wild Dog, Sargonne (? Sardine), Clear Water, etc. The remaining Northern boundary of the Werribee basin is the Gisborne ridge, which is separated from the main Divide by the eastward trending valley of the Gisborne Creek, a tributary of the Saltwater River.

The nature of the Divide may perhaps best be followed by descriptions from various viewpoints along its course in this area. On the whole it stands up very little above the general level of the lifted peneplain block which it traverses. The three highest points visited by the writer are each due to the accumulation of volcanic material. These points are:—

(a) Leonard's Hill.
(b) Old Bullarto.
(c) Wuid Kruirk.

(a) Leonard's Hill is a rounded volcanic cone clothed with fertile soil, standing at an elevation of 2500 feet (aneroid). It is right on the Divide, and close to the railway station of Leonard (Ballarat-Creswick line). To the north rise the head waters of the Jim Crow Creek, a tributary of the Loddon, while on the southern side are small tributary gullies which lead to the Werribee and the Eastern Moorabool. Fine views are obtainable; to the east the Divide continues in densely timbered Ordovician ranges, well seamed by gullies of very moderate relief. To the West, this feature has a similar aspect, except that a high timbered ridge occurs, and partly shuts out the view; far to the west, however, may be seen the dim blue outlines of the parallel N.S. ranges of the highlands of Western Victoria (ref. 22).

The aspect of the Divide, where it lies in the Ordovician and appears most likely to have been uninfluenced by the newer basalt flows, is what one would expect to find where two sets of streams, flowing in opposite directions, were competing for territory by headward erosion. Possibly the predisposing causes of the two opposite flowing sets of streams already existed on this block of upland itself. On the other hand, the factor which gave the streams their present directions might have been the let-down country to the N. and S.; creeks and rivers would then head back into the highest block, almost independently of the surface-levels of that block. The lifted block may even then, of course, carry on its surface a set of stream channels which existed on the ancient peneplain.

It would seem probable that the old uplifted block originally had a more extensive northern slope than is the case at present, so that longer consequent streams on that slope would be competed against by vigorous streams heading back from the south. The southern rivers, having a markedly shorter course to the sea, have a great advantage in average grade, and are the more vigorous streams. Thus it was found all along the Divide in this area that the deeper valleys and the more vigorous erosive work was being done on the south, with consequent northern migration of the Divide.

Four miles further eastward (slightly N.E.) is another area of volcanic material, at Bullarto. The intervening Ordovician ranges are almost uninhabited, and no roads cross that area. We must therefore travel northward to the mining town of Daylesford and southward again to Old Bullarto. Both roads lie mainly along converging tongues of basalt, which preserve old north flowing valleys.

The rich agricultural village of Old Bullarto lies right on the Divide, a mile or two south of the railway station of new or north Bullarto. The latter station long enjoyed the distinction of being the highest in Victoria (2452 feet). An old railway survey, coming across the ranges from the south, crosses the Divide at Old Bullarto (2610 feet). The basalt flows which here form the Divide are not extensive, but are highly cultivated, and crown the range with rich farms. To the north the Wombat Creek and Kangaroo Creek flow to the Loddon, both rising within the township, and having here low, swampy courses, although deepening further north. In this township also we may find the sources of the two main rivers of our area—the Lerderderg and the Werribee.

Here again we find the more vigorous work being done by the southern streams, especially by the Lerderderg. The actual source of the Werribee River is somewhat swampy, though deepening rapidly further south. A small N.-S. ridge divides the Werribee from the Lerderderg, and the latter stream is conducting a very vigorous erosive campaign, forcing the Divide to the north.

To the east of Bullarto there is a high timbered hill, locally called Coghlan's Hill, and apparently of Ordovician. Beyond that, lava flows, mainly extending to the north, again form the Divide (Fig. 15); the highest point of this volcanic area is Wuid Kruirk (2800 feet), also the highest point in the Werribee area. Magnificent views are obtainable from this Mount, mainly to the southward, right across the great uplifted peneplain blocks, boldly cut through by the valley of the Lerderderg, and beyond again to the Werribee plains, and thence to the sea. Looking south, the line of the Greendale fault can be clearly detected, running east and west, and separating the heavily-timbered ranges from the open country beyond. While the sides of this hill (Wuid Kruirk) are clothed with timber, the summit is a bold, bare bluff, and the views in all directions are thus unimpeded.

The Divide, which runs nearly E.-W., from Old Bullarto to Garlick's Lead (Newbury), now turns sharply N.E., no doubt due to vigorous work being done here by a strong S-flowing tributary of the Lerderderg. Ferguson (ref. 18), who examined the sub-basaltic alluvials at Garlick's Lead, found evidence therein of a northern migration of the Divide. The north-pointing salient east of Wuid Kruirk is in Ordovician rocks, and the Divide turns southward again at the volcanic area of East Trentham. Thence it continues south easterly in Ordovician to the head waters of the Campaspe, and so out of our area. There is a low pass through the Divide at the point separating the Campaspe from Gisborne Creek, and through this a survey has been made for a projected Holden-Trentham railway; this survey crossed the Divide at 2376 feet. The somewhat flat, and occasionally swampy, valleys of the Campaspe and Gisborne Creek, near their sources, contrast strongly with the steep-sided valleys of the Lerderderg and its tributaries.

While examining the Divide in this area, unsuccessful effort was made to find evidence in favour of Gregory's "Primitive Divide" having at all affected the present topography. While touching on this matter the writer would wish, only for a moment, to enter into the controversy regarding this postulated ancient range.

Professor Gregory (ref. 20), to whose inspiring work Victorian physiography owes so much, appears to base this theory of the "Primitive Mountain Chain," largely on the linking up of selected masses of Plutonic rocks, the exposures of which are believed to have an east-west trend across the highlands of Victoria. T. S. Hart (ref. 22, p. 264, etc.), advances strong evidence against the correctness of this hypothesis.

It is to be expected that we could get the most correct reading of our physiographic and geological history by linking up both with the known facts of South-Eastern New South Wales. A sketch (Fig. 17), has therefore been prepared to show the actual distribution of the plutonic masses of the south-eastern part of Australia. As might be anticipated, this sketch shows that the general trend of he pluntonic masses is similar to the general trend of the axes of the great folding movements that affected our lower palaeozoic rocks. The plutonics of South-Eastern New South Wales are seen to be definitely elongated along north-south lines, strikingly shown in

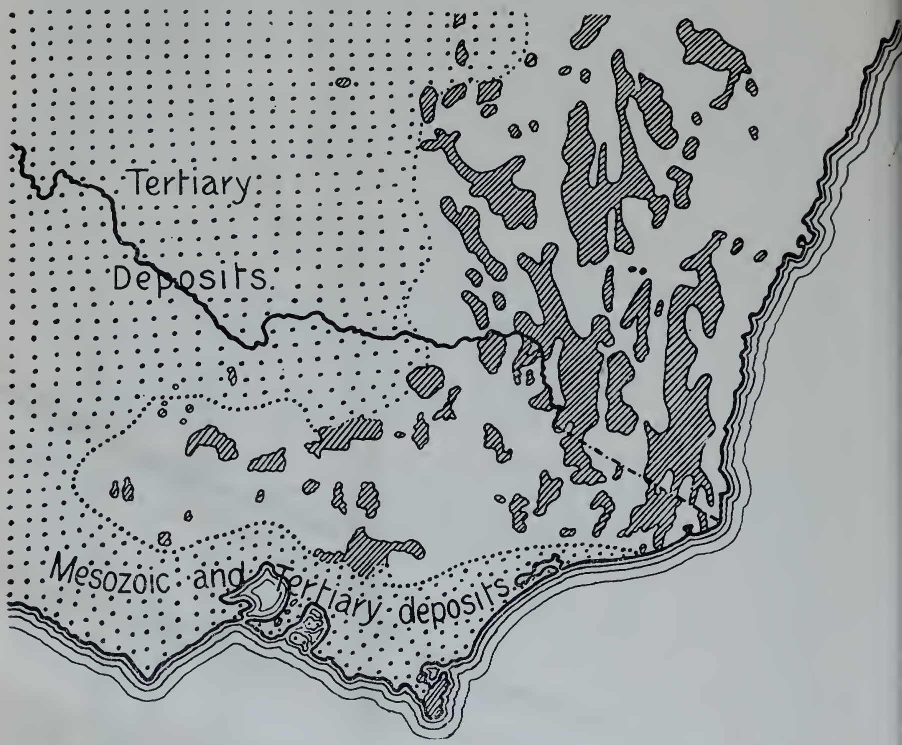


Fig. 17.—Map showing the distribution of granite exposures in South-Eastern Australia, and indicating the predominance of elongation along North-South axes. In addition to the covering of younger sediments shown dotted, other granite areas are doubtless obscured by rocks of Carboniferous and subsequent ages.

the latest geological map of that State. In Victoria the occurrences are fewer, with a greater area obscured by later sediments and volcanics; still, a general elongation in a north-south direction is observable. Had the sketch been continued southward to include Tasmania, this point would have been further emphasized, especially in the better known granitic areas of the north-eastern part of the island. The great mass of the Strathbogie ranges in Victoria certainly appears to trend east-west, but close observation shows that it may not always have been of this shape. To the north this mass is of gradually lower relief, and is finally covered over by the tertiary deposits of the "Murray Gulf," etc., while on the south, the nature of the junctions strongly suggests that part of the mass had been faulted down. Similar observations may be made regarding other masses. In the case of the great horeshoe-shaped Harcourt exposure, and many others, the marginal lines trend north-south just as much as they do east-west. These plutonics certainly do not appear to present sufficient evidence for the assumption of a great continuous east-west range of mountains.

T. S. Hart, who has given his attention for many years to the question of the origin of the Main Divide, stated in his paper before the B.A.A.S., at Melbourne, 1914, (ref. 23, p. 443), that "the actual intrusion of the granitic rocks has taken no part in forming the present Divide."

The fact that the intrusion of our pluntonics is known to have been wholly palaeozoic (? Devonian and earlier), and associated with intense folding along north-south lines, would also suggest that any mountain ranges associated with those plutonics were also palaeozoic, and with a north-south trend.

(ii.) *The Block Ranges.*

(a) *The Blackwood and Lerderderg Ranges.*—These ranges constitute the whole of block A (see Plate XI. and Fig. 2), and are bounded on the west and north by the Werribee River and the Main Divide respectively; on the east and south are the well-defined scarps of the Rowsley and Greendale faults. Either of the two names given above is used to designate these ranges, the former being derived from the prominent volcanic hill (Mt. Blackwood), or from the once thriving goldfield of that name, situated in the northern part of the ranges. The alternative name is due to the Lerderderg River, which has carved a deep valley right through the whole block from north-west to south-east. As already pointed out, these ranges are almost wholly of hard, resistant, folded slates, sandstones and quartzites of Ordovician age, levelled to a peneplain by river action, and later uplifted and dissected. The average level is about 2200 feet.

The general plan on which dissection has proceeded is set forward as under. It must be remembered that most of these ranges and streams are unsurveyed, and most of the surveys which do exist are scrappy and old (as we count time in Victoria). More recently the mining area of Blackwood, and the saw-milling village of Blakeville have been surveyed, while the Commonwealth Military

Survey has published contour plans, which extend over the southern portion of the block. An effort has been made (Fig. 18) to indicate the general direction of the ridges and valleys in this lifted block. As already mentioned, the Lerderderg and its tributaries have done nearly all the work. Between this stream and the others concerned, residual ridges occur, and help to provide the easiest regular "tracks" across the ranges.

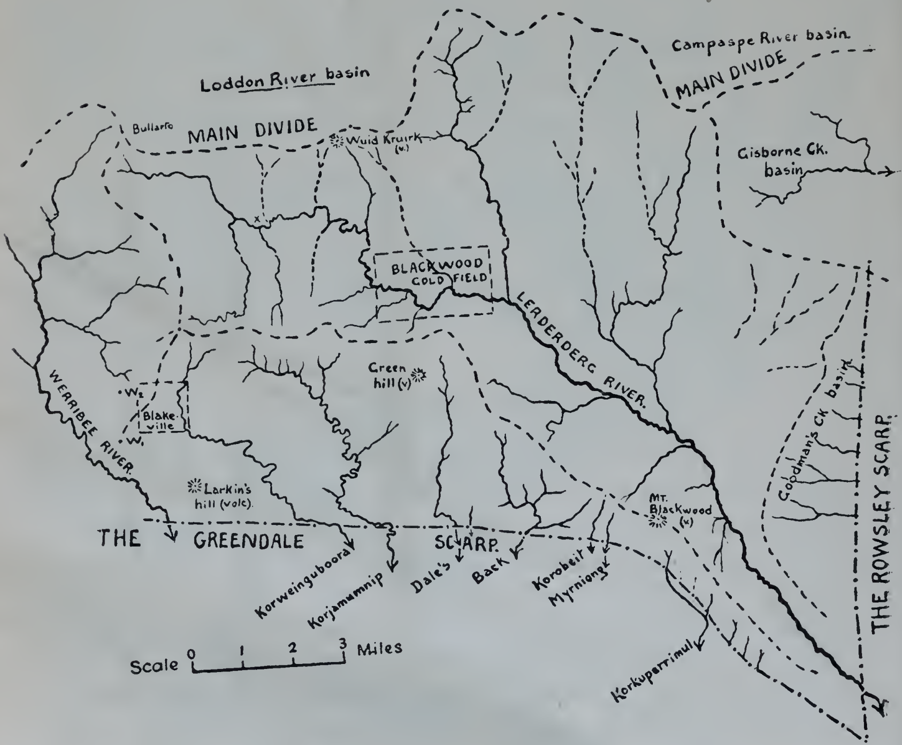


Fig. 18.—Streams and Divides of the Blackwood and Lerderderg Ranges. (V) — volcanic hills.

It will be seen that there is a high knot of country to the north of Blakeville, from which streams flow in all directions; an irregular ridge connects this with the Main Divide at Bullarto, forming a north-south divide between the Lerderderg and the Werribee. Another long ridge runs east and south-east beyond Mt. Blackwood, separating the Lerderderg from the south-flowing tributaries of the Werribee—the Korweinguboora, Korjamunnip, Dale's, Back, Korobeit, and Korkuperrimul Creeks. The writer's conception, which will be elaborated when dealing with the individual streams, is that the Lerderderg is not only the dominant stream of the whole Werribee basin, but is also the most ancient, and probably inherited its course from an ancestor which existed on the ancient peneplan. While the long northern tributaries of the Lederderg appear to have maintained their courses, and increased their territory northward (see Fig. 18), new post-uplift streams on the east and south, with steep grades and softer rocks to help them, appear to have captured part of the old Lerderderg basin.

(b) *The Brisbane Ranges.*—Here again we have a huge uplifted block of folded Ordovician, structurally and lithologically quite similar to the Blackwood ranges, and similarly containing a once-important, centrally-situated mining field (Steiglitz). The boundaries of this block are not clearly defined, and the name is generally applied only to the eastern part, the western portion being in part covered by alluvium and basalt flows, cut through by the deep gorge of the Moorabool River. The general level of the block is about 1200 feet, sloping towards the south and west. The northern boundary of the ranges is the Spring Creek, while on the east is the remarkably well-defined scarp of the Rowsley fault.

Davis (ref. 16) says:—"The simplest and most manifest element of faulting along a mountain base is a straight or but moderately curved base line, passing indifferently across or obliquely along the structure of the mountain mass, which rises rather abruptly and continuously on one side, while a sloping plain of waste is spread out on the other." The field evidence along the whole east front of the Brisbane Ranges shows that here we have a feature exactly fulfilling these conditions. This steep portion is dissected by numerous tributaries of the Little River, while the southern half is deeply cut into by the various branches of Sutherland's Creek.

(c) *The Ballan Plateau.*—This structural unit is what we have so far referred to as block B, or the Ballan sunkland. Although a sunken area with reference to the Brisbane and Lerderderg Ranges, it is relatively lifted about 1000 feet above the plains of the lower Werribee—the Port Phillip Sunkland (see block diagram, Fig. 3), and since the main lines of communication between Melbourne and Ballarat give an emphasis to the sudden rise above the scarp face, it is more popularly known as part of the "Ballarat Plateau." Structurally, it is of much greater complexity than either of the two blocks already described. It would appear to have been greatly faulted within its own boundaries, and consists of Ordovician slates, etc., glacial sandstones and conglomerates, older volcanics, middle tertiary sands, clays, etc.—all largely covered by the later volcanic lava sheet.

It is deeply cut into by the Parwan, the Werribee, and minor streams in the east, and by the Moorabool in the west. These streams however have not carved the area into a maze of ridges, as is the case in the Blackwood and Brisbane ranges; a result largely due to the preserving influence of the newer basalt sheets. An isolated patch of extensively dissected Ordovician and granite occurs to the south of Werribee Gorge, where small tributaries of the Werribee and Parwan have done a vast amount of work; this area was never covered by the newer basalt sheet. The nature of this locality is strikingly seen from the railway line between Bacchus Marsh and Ingliston, since the line travels along somewhat above the general level of the isolated patch of timbered ranges.

(d) *The Gisborne Highlands.*—The western portion of this high area is Ordovician, and that rock also probably underlies the whole of the eastern part, the present surface of which is newer volcanic. The Ordovician at the head of Pyrete Creek stands at a distinctly lower level (2-300 feet) than the ranges immediately to the west (block A), but they are some 7-800 feet higher, on the average, than the volcanic portion of the Gisborne highlands further eastward. The general levels of this "block" are much less as we go eastward, grading down to that generally lower portion of the Victorian Highlands that marks the "Melbourne-Echuca line" referred to by Taylor (ref. 52) as the Kilmore geocol.

(iii.) *Residual Hills.*

(a) The *You Yangs.*—The name of this impressive range is evidently a corruption from the recorded aboriginal name of Wurdi-youan. It is historically the most interesting point in the area, on account of its ascent by Matthew Flinders in 1802.

Fig. 19 shows the outline of this very familiar landmark, drawn to true scale and projected from the contours of the Military Survey. The mass is wholly granitic, although a small outcrop of the intruded Ordovician slates occurs at one place. The You Yangs must have formed a striking monadnock on the ancient peneplain; there is no doubt that it owes its origin to the highly resistant nature of the rock of which it is formed. Alluvium and lava flows surround the base, and the apparent height of the mount is exaggerated by the extremely level nature of the surrounding plains. These hills have already been dealt with in complete detail by Professor Skeats (ref. 46). A low and irregular granitic ridge continues from the You Yangs to the Anakies, and forms the southern boundary of the Little River basin.

Fig. 19.—Contour of the granitic monadnock of the You Yangs, as seen from the South-East or North-West, true scale, projected from the contours of the Commonwealth Military Survey.

(b) *The Anakies.*—These are only in part residual in origin, since the most impressive portion of the group known as the Anakies consists of high accumulations of volcanic materials. The group loses in impressiveness from its position on the lower of two neighbouring blocks of country.

The early recorded name of the Anakies was Anaki or Anikai) You-wan. As the latter part of the parallel names was retained for the You Yangs, so has the first part of the name of this group come to be the generally accepted one. The granite portion of the Anakies is less than 1000 feet in height, and shows some fine large granite tors. Like the You Yangs, this hill was undoubtedly a monadnock on the ancient peneplain. No similar granites occur in any other part of the Werribee River area, as far as known. This granite appears to be much more resistant to erosion than are the granodiorites of the Werribee Gorge and elsewhere.

(c) *Trig Hill, etc.*—Here we may include a number of lesser hills that have been formed by the dissection following the recent uplifts. They are therefore very much younger features than the You Yangs and Anakies, having their origin subsequent to the newer volcanic period. A number of such hills occur, nearly all of them in the Ballan Plateau. Structurally, they show great variety, and provide interesting examples of differential erosion.

Among them we may specially mention Trig Hill, Pentland Hills, and "the Island"—all of which are due to the great valleys carved by the Werribee and Myrniong. Their tops are really portion of the fairly level block of the Ballarat Plateau. Trig Hill (sometimes known as Table Top), an important trigonometrical point, is well known to those who travel by rail through Bacchus Marsh. It stands on the left bank of the Werribee, about a mile above the point where the Korkuperrimul enters that stream. As will be seen from the sketch it has a complex structure of older basalt, tertiary beds, and newer basalt, the influence of each formation being shown in the varying slopes.

The Pentland Hills are better known to travellers by road, the V-shaped valleys which have formed them being somewhat impressive in appearance. They mark an area of good pastoral country,

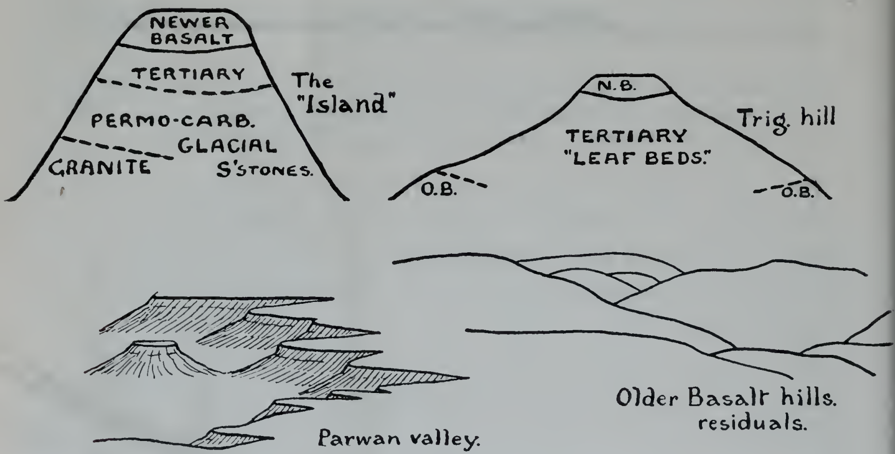


Fig. 20.—Diagrams and sketches of various residual hills in the Ballan Sunkland, as detailed in Section IXa. O.B.—Older Basalts. N.B.—Newer Basalts.

and were early settled; these hills were among the very few features of the Werribee area referred to by Brough Smyth (ref. 49). Professor David has also felicitously described them (ref. 13).

Close to the Pentland hills is "The Island," formed in the loop between the Myrniong and the Werribee, above their junction (see Fig. 36.) This feature is surrounded on three sides by deep valleys, and there is a low wind-gap on the fourth side. To use the phrase of Mr. C. C. Brittlebank, this part has been "thrice a valley and now a hill." The base is mainly glacial, and we may fairly assume a valley for the glacier. Above this formation tertiary leaf beds occur—probably fluviatile, giving us a second valley period. In these beds at a later date, was eroded the (third) valley of the "ancient Myrniong," now filled by newer basalt; resistant basalt now caps "the Island," and erosion on both sides has given us the "hill." The sketches shown in Fig. 20, indicate the structure and the different outlines resulting therefrom, so that no further description of this group of residuals is necessary. The sketches are mainly diagrammatic.

(d) *Mt. Wilson.*—This hill presented some difficulties to the writer. In the absence of any accurate and detailed surveys of the north part of the Werribee area, every available map that included any portion of those ranges was closely examined for topographical data. This was done as a preliminary to the actual field work, and one of the few features noted on such maps was a Mt. Wilson, near Blakeville. On Ham's Map of 1847 (on a tracing by Mr. Barnard), this hill is shown, spelt Wilsone. The county plan of Bourke, and the large maps of the State also show it as standing to the south-west of Blakeville (see W_2 Fig. 18). The geodetic sheet that includes this area shows it as being north-west of, and close to, Blakeville (see W_2, Fig. 18). Among the complex maze of blue ranges there, the writer naturally expected to see this feature standing somewhat above the general level. This was not the case, and frequent enquiries from bushmen who knew the country well, pointed to the fact that while there was a well-known hill of that name in the ranges, it was in a very different position from either of those shown on the maps. The real Mt. Wilson lies about half way between Old Bullarto and Blackwood townships (roughly about X, Fig. 18), and is a residual, in the preservation of which lava flows appear to have played a part. It was noted from many points by the writer, but not visited. Mr. A. Blake, of Ballan, who knows all the Blakeville country thoroughly, has written confirming the writer's view that no Mt. Wilson exists where marked in all our current maps.

Volcanic Hills.

(a) The highest peak in the area, Wuid Kruirk (Blue Mountain), has already been described. Its real height as a volcanic hill is no more than 500 feet, the remaining 2300 feet being the height of the Ordovician block on which it stands.

(b) Next in order is Mount Blackwood (2432 feet). This hill stands almost centrally within the Werribee River basin, and is visible from practically every part of that area. Like Wuid Kruirk, the height of the volcanic portion is only about 400 feet, and Blackwood stand on the same uplifted block, close to the southern scarp. This will be clearly seen from Fig. 21, which shows a plan and section of the cinder cone, and the main lava flow therefrom. The dotted line in the section marks the general level of the old peneplain surface. There is very little trace of a crater. The old county map of Bourke shows the hill as "Mount Blackwood, or Myrniong." In a letter written by Mr. W. H. Bacchus in 1876 (ref. 59), he states: "Mt. Blackwood was then (1836) known as Clarke's Big Hill." In Major Mitchell's Map of

Australia Felix, 1836, the same hill is, however, marked as Mt. Blackwood (ref. 60). The back files of the Ballan Times record that the Mount was so named after one "Captain Blackwood, com-

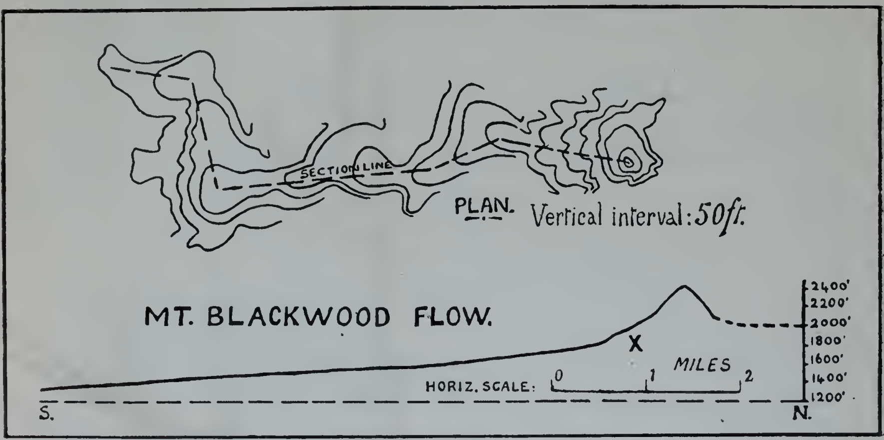


Fig. 21—Contour plan and longitudinal section of the Mt. Blackwood lava flow.

mander of the 'Fly,' 1842-45." Magnificent views are obtainable from the summit of this hill.

(c) *Mt. Bullengarook.*—This volcanic hill also stands on a high base of Ordovician slates, which outcrop on the road that winds round the foot of the hill, at a height of 1900 feet; the total height of the hill is 2207 feet. A contour plan and a section of this hill and the southern lava tongue is shown in Fig. 22. It will be noted that about 4-5 miles from the hill, the flow descends somewhat steeply, and here the Pyrete creek on the east and Goodman's

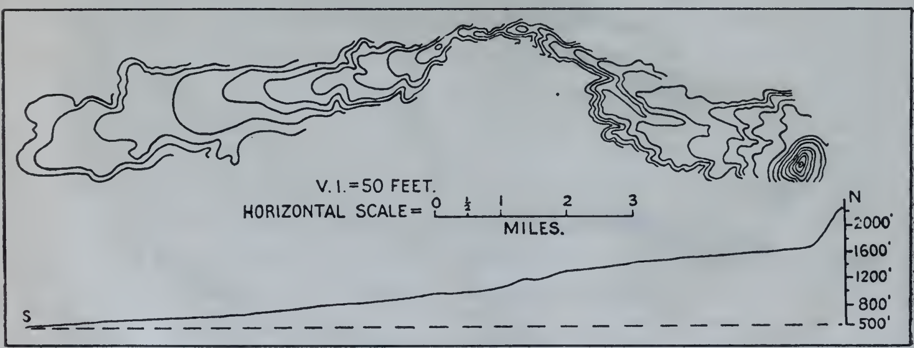


Fig. 22.—Contour plan and longitudinal section of the Mount Bullengarook lava flow The "bight" on the eastern side is largely due to erosion by Pyrete Creek.

creek on the west have carved their valleys back, stripping off the basalt, and in places laying bare the ancient river gravels. A little to the east of Bullengarook is the lower hill (also volcanic) of Little Bullengarook. They stand on the ridge which forms the divide between the Werribee and the Gisborne Creek. An older spelling of the name was Bullancrook.

(d) *Mt. Gisborne and its neighbours.*—Mount Gisborne (2105 feet). This is a similar volcanic hill, but much more irregular in outline than those already described; it would appear to have produced more extensive lava flows than the hills dealt with above. Although not so high as Bullengarook, Gisborne is the dominating feature of the east-west ridge that forms the divide between the Werribee and Saltwater basins at this place. To the east and south-east, volcanic hills are numerous, and among them may be mentioned Mounts Aitkin (1644 feet), Red Rock (1640 feet), Holden (1360 feet), and Kororoit (779 feet).

(e) *The Anakies.*—Mention has already been made of the Anakies, and little remains to be added here. The volcanic portion of the group comprises three high, treeless, volcanic hills, the most important of which is close against the Rowsley Scarp. Between that hill and the scarp the Anakie Creek has cut its valley, the upper part of which has probably been captured by the Little River. The highest of the volcanic domes is called Mt. Anakie (1350 feet). It is by far the largest single volcanic hill in this area.

(f) *Volcanoes of the Lower Plains.*—Here we have a series of well-known hills. They include Bald Hill (731 feet), Spring Hill (700 feet), Mt. Cotterill (669 feet), Mt. Mary or Green Hill (476 feet), Mt. Atkinson (459 feet), and other lower points of eruption. Mt. Cotterill has a most characteristic shape, and may be easily recognised from a distance on account of its peculiar flat top. Mt. Mary is well known as a breached crater (Gregory, ref. 20), and also possesses interesting geological features very fully described by Kitson (ref. 37). North of Spring Hill, at Nerowie, there are two large natural basins—the northern and larger one being a complete basin, while the one to the south has an outlet; both are cultivated. They undoubtedly represent well-preserved volcanic craters, possibly enlarged by subsidence.

(g) *Volcanoes about Ballan.*—Here again we have a number of hills, whose outlines in most cases are familiar to travellers between Ballarat and Melbourne. The better known ones include Larkin's or Bald Hill (2300 feet), Steiglitz (2090 feet), Gorong (1800 feet), and Darriwill (1700 feet), while the less known are Ingliston, Hydewell, and "Rae's Hill" The heights given will be noted to much exceed the last-described group of hills, the difference being due, of course, to the positions of these points of eruption on the relatively lifted block of the "Ballarat Plateau."

Larkin's or Bald Hill is a small hill, but owes its greater elevation to the fact that it stands above the Greendale Fault line, just within the timbered country. It is a cinder cone, with the latest breach to the north-west, the lava from this point assisted in forming the newer basalt tongue which flows across the fault line near by. (See Fig. 8.)

Steiglitz is quite treeless and is a low rounded dome with no sign of a crater. Large erupted blocks occur on its summit and slopes, and it has also been the point of origin of a good deal of lava. Gorong is a wooded hill, very scoriaceous, and the northern and western slopes show successive outcropping steps of lava, giving it a peculiar terraced appearance. Darriwill is closely similar to Gorong, and it would not appear that either volcano had ever been greatly effusive. Ingliston is a very small hill, north of the Ingliston railway station. The particular interest of "Rae's Hill," which occurs on "Highton," near Greendale, is its insignificance as a landscape feature. It is an undoubted point of eruption, and yet its elevation above the general level of its flow is only to be noted by close observation. Finally, we come to Mount Hydewell, in many ways one of the most interesting of the group with which we are now dealing. It lies something over a mile south of Ballan, and has a grade so gentle as to be almost imperceptible; yet there seems no doubt that from the point of view of lava production, it is the most important volcano in the district. There is some very vesicular material about the top of the rise, but it would appear to have had very little explosive activity, and hence did not build a cone. This is evidently the point referred to by Mr. Hart (ref. 22), as "an unnamed centre near Ballan." Small streams flow from Mount Hydewell :—

N. and E. to the Werribee River.
E. and S. to the Parwan and Yaloak Creeks.
S. to a swampy area near Mt. Wallace.
W. and S.W. to the Moorabool River.

It probably had a very big destructive effect on the old physiography here and undoubtedly exercised great influence in the location of the present river channels.

(b) *Rivers and Valleys.*

The Werribee River basin as a whole will first be dealt with, in its relations to the neighbouring river basins; then the Werribee in relation to its own tributaries, and finally a detailed description of each river, concluding with an account of the "buried rivers."

(i.) *The Werribee Basin and its Divides.*—The general relations between the Werribee River and neighbouring streams are set out in Fig. 23. On the lower plains we find the Little River and another small stream (Cherrytree creek) adjoining the Werribee on the south, with a very gentle rise acting as divide between them. In the northern part of the plains the relatively high ground around the volcanic centres of Bald Hill and Spring Hill forms a natural divide between the Werribee and the Balliang Creek, a tributary of the Little River. Further seaward this divide is continued in the general rise around Mt. Mary or Green Hill. Thence to the sea the ordinary gentle irregularities of the volcanic plain have determined the limits of the two basins.

The southern tributaries of the Parwan have penetrated very slightly into the Ordovician block of the Brisbane Ranges, having found much easier courses in the soft, level-bedded tertiary sands and clays. Here the fault line bounding the southern edge of the Ballan Sunkland practically forms the divide. The Brisbane Ranges are here drained by headwarter streams of the Little River on the east, and by Eclipse Creek, a tributary of the Moorabool, on the west. The higher ground around Mt. Wallace (volcanic), also helps to form the divide between Eclipse Creek, a tributary of the Moorabool, and Spring Creek, a tributary of the Parwan.

Coming now to the west, the Werribee is bounded in that direction by the basin of the eastern Moorabool. This is a strong, south-flowing river, with a deep young valley cut mainly through the newer volcanic sheet into the Ordovician and other rocks below. The boundary (between the Werribee and the Moorabool, is very low.

Much speculation has been indulged in as to whether the eastern Moorabool originally (in pre-newer volcanic times) flowed into the Werribee, or vice versa, or whether both streams may have been tributaries to a hypothetical ancient Parwan. The area was closely examined for evidences as to this. The point west of Ballan, where the eastern Moorabool takes a sharp loop eastward, so that only a mile of level country separates the two young channels (Moorabool and Werribee) was specially examined. The Werribee here lies wholly in the basalt, while the eastern Moorabool has cut down through that rock into Ordovician and glacial. There are no sections of old basalt-filled valleys here, as far as the writer could determine, except one close to the Bradshaw's railway station, cut through by the eastern Moorabool. This old stream no doubt flowed to the east, and may be regarded as the ancestor of Paddock Creek.

West of the Eastern Moorabool, and within the easterly loop above referred to, there are comparatively high, rough hills of folded Ordovician slates, with many small patches of glacial sandstones, and flanked on the north by ferruginous tertiary grits. The area was no doubt high land in pre-newer basaltic times, and this fact suggsts the presence of a broad valley extending in width eastward beyond Ballan. This would indicate that the upper streams of the present Eastern Moorabool and Werribee were at that time united in this area.

As we go further north the Ballan to Daylesford road follows the divide between the Moorabool and Werribee basins, as also does an old railway survey. The divide here is still very low and flat, with many swamps; some of these drain to the Eastern Moorabool and some to the Werribee. The rocks are volcanic, capped by sand and buckshot gravels, fairly well timbered. This continues to near Bunding, where the high flat-topped volcanic cone of Egan's Hill separates the two rivers. Further north we descend from the volcanic sheet, and pass to the Ordovician ranges which lie north of the Greendale fault line. The road is here very bad, and the grades much steeper. The Eastern Moorabool (here the site of the Korweinguboora reservoir, Geelong Water Supply) is on the whole in a much more mature valley than is the Werribee. The latter shows that an old lava stream originally filled its course here, but that has now been mainly carved away, and remains only as basaltic patches, underlain by river gravels, somewhat above the present level of the valley bottom.

This country forms part of the State Forest, and is thickly timbered with big eucalypts, blackwoods, scrub, bracken, etc. A lava flow coming down this valley at the present day would have its progress very greatly impeded by this timber, which grows right to the bottom of the valley. The thought arises whether the ancient lava-buried valley was similarly timbered, and if so what became of the trees. Probably very severe "bush fires" would accompany the flows of the molten lava.

Still further north, at the Mineral Spring Hotel, the divide between the Werribee and the Moorabool is an insignificant Ordovician ridge about 50 feet high and a mile or so wide. Immediately to the west, the divide between the eastern and western branches of the Moorabool is much higher, in similar rocks, and three miles wide. It might be expected that, accidents excepted, the divide between any two well-established streams should be more marked than between any two tributaries of one of those streams, when the same rock type prevails. The facts thus suggest that in pre-newer volcanic times the upper Werribee, and the upper Eastern Moorabool were tributaries of the same system, the separation having been effected by Egan's Hill and the lava flows therefrom.

The country rises considerably through the village of Korweinguboora, towards the Main Divide at Leonard's Hill. At Korweinguboora there are two south-sloping, much decomposed tongues of basalt. A shallow valley on one of these tongues leads to the Werribee, while a similar tributary gully of the Eastern Moorabool runs along the western side of the same flow. The country thence rises to Leonard's Hill. This point is on the Divide, and has already been described.

Thence eastward, the Main Divide of Victoria separates the Werribee on the south from the Loddon and Campaspe Rivers on the north, as detailed in a previous section. On the whole, the Divide here is migrating northward. No captures from the northern rivers are to be noted, and the advance northward by the head waters of the Werribee and the Lerderderg is more in the nature of a general "nibbling" along the whole front, rather than a sudden acquirement of large territories by captures.

From the Main Divide, south-east about seven miles to Mount Bullengarook, the divide separating the Werribee basin from that of the Gisborne Creek (a tributary of the Saltwater), is in thickly-timbered Ordovician country. Enquiries from saw-millers who had been through that part elicited the fact that a rough bush track runs along this divide from Bullengarook to East Trentham. This was not examined, but the steep ravines that were seen to mark the headwaters of the Goodman's Creek and the Lerderderg, when compared with the wide valley of Gisborne Creek, point again to the more vigorous work being done in the basin of the Werribee.

From Mt. Bullengarook the divide is irregular, running generally eastward through Mt. Gisborne. It is partly a high, well-dissected Ordovician block, largely covered by basaltic hills and flows. The gully heads of the Pyrete or Coimadai Creek, the

Djerriwarrh or Deep Creek, and (to a less extent) the Toolam Toolern Creek, are deeper and steeper-sided than those flowing northward from this divide.

While the three creeks just referred to flow southward to the Werribee, there is a fourth parallel stream going southward—the Kororoit Creek—which turns east on reaching the low basalt plains, and enters the Bay independently. This course was evidently selected owing to minor irregularities in the surface of the volcanic plains. To follow the divide between the Werribee and the Kororoit Creek basin, we must now descend from the Gisborne highlands, and travel southward.

The western branch of the Kororoit Creek, in the higher levels, is very closely related to the eastern branch of the Toolern Creek, and minor captures appear to have taken place. On the plains, from near Melton down to the sea, the divide is low, with few and small irregularities similar to that between the Werribee and the Little River already described. Between Kororoit Creek and the Werribee a small valley (the Skeleton Water Holes) comes from the slightly higher country about Mts. Cotterill and Atkinson, and helps to drain the plains, flowing directly into the sea.

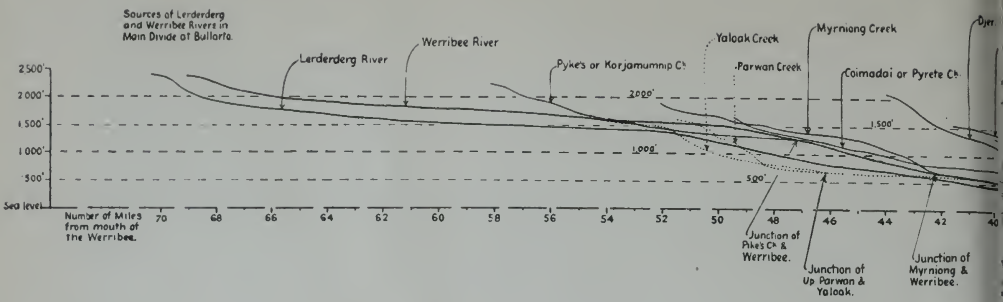
(ii.) *The Werribee River in relation to its own tributaries.*

The complex nature of the Werribee and its tributaries will be seen from a reference to the special river map (Plate XIIA.), and the grade profiles of the Werribee (Plate XIIB). It may be here explained that the plan of the Werribee and its tributaries has certain imperfections; it is based on the county plans of Bourke and Grant, and where the streams were unmarked in those maps, an effort was made to complete the map from other sources. The

Fig. 23—Characteristic longitudinal section, showing relative grades of a stream and its tributaries, after Nussbaum (ref. 32).

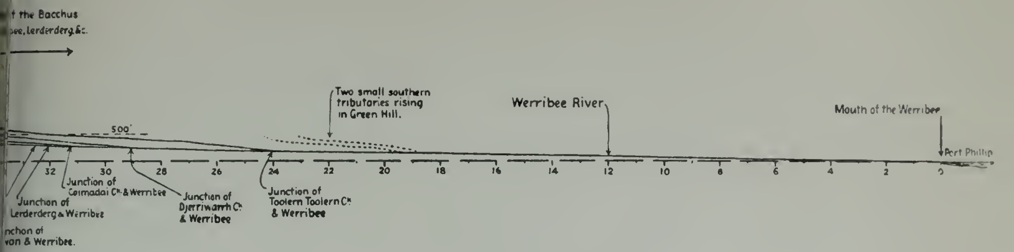
general plan of the main streams is quite correct, but exactness is lacking in the tributaries of Goodman's Creek, the upper Pyrete, and the Lerderderg.

It may also be explained that the grades of the rivers and creeks were plotted from levels supplied by the published maps and field notes of the Military Survey, supplemented in the unmapped parts

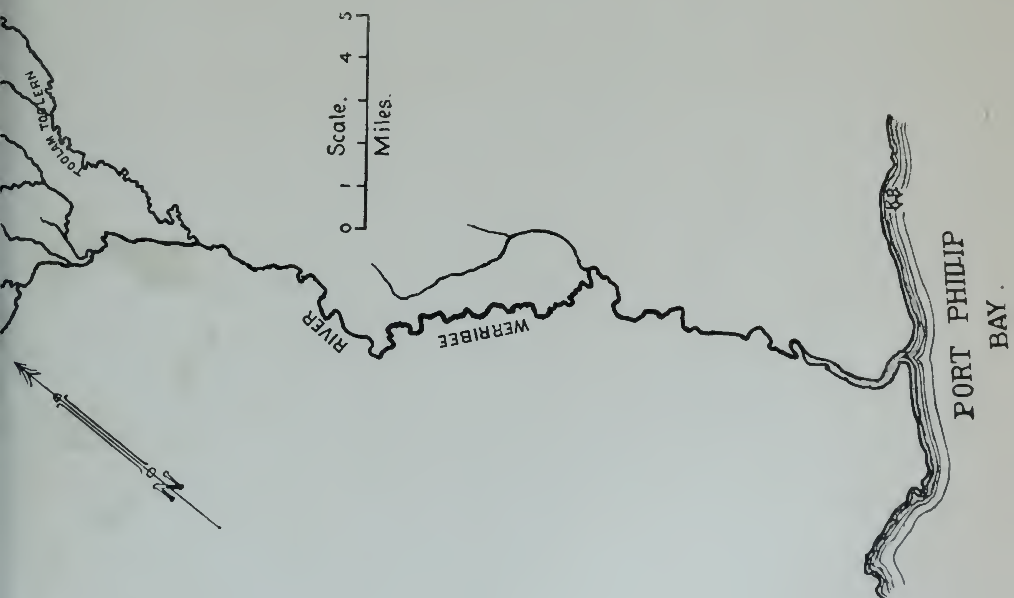


Sources of Lerderderg and Werribee Rivers in Main Divide at Bullarto.
Lerderderg River
Werribee River
Pyke's or Korjamumnip Ck.
Yaloak Creek
Parwan Creek
Myrniong Creek
Coimadai or Pyrete Ck.
Djer
2500'
2000'
1500'
1000'
500'
Sea level
2000'
1500'
1000'
500'
Number of Miles from mouth of the Werribee.
70
68
66
64
62
60
58
56
54
52
50
48
46
44
42
40
Junction of Pike's Ck. & Werribee.
Junction of Up Parwan & Yaloak.
Junction of Myrniong & Werribee.

MAIN
DIVIDE
UPPER LERDERDERG
KORJAMUMNIP Ck.
BACK Ck.
DALE'S CREEK
PYKE'S Ck.
KORWEINGUBOORA Ck.
WERRIBEE RIVER
LERDERDERG RIVER
KOROBEIT CREEK
MYRNIONG Ck.
KORKUPERRIMUL CREEK
LYELL'S
GOODMAN'S CREEK
OR COIMADAI Ck.
BOGGY Ck.
DEEP CREEK
CREEK
PARWAN
YALOAK Ck.



~~A~~ B Profile sections, to scale, of the valley bottoms of the Werribee River and its chief tributaries.



~~B~~ A General plan of the Werribee River and its tributaries.

by aneroid records taken by the writer. The idea of plotting the grades thus was suggested by a similar piece of work by Nussbaum (ref. 32). Nussbaum's diagram has been carefully re-plotted on a larger scale, and turned in the opposite direction (Fig. 23), to afford easier comparison with the profiles of the Werribee River and tributaries (Plate XIIB.).

The great variety of river types in the Werribee area is due to four outstanding facts. The first of these is the variety of the rock types, which has already been referred to, and the other three include the two important periods of differential uplift, and the great newer volcanic period. Each factor has left its impress on the present river system.

Before proceeding to discuss these factors, the question arises: Which is the dominant stream, the "name-stream," of any river? The matter is important from the physiographic and cartographic standpoints. A physiographer, regarding a map of any river, may conceive it as lopsided, receiving most of its trubutaries from one side only, when perhaps the fact may be that a minor or tributary stream has been given the "name-dominance," by an error of judgment. Similarly cartographers doing small scale maps only include the main stream, according to the name thereof, and if that has been badly selected, the map does not truly represent the facts.

The writer conceives this to be the case in the Werribee area. It may be shown that from the point of view of depth, age, length and volume the Lerderderg is the most important branch of the Werribee System. Economically, however, early settlement of the area trended more along the present day upper Werribee. In 1845-6, when Hoddle, Darke and Urquhart surveyed the Werribee, etc., as part of the boundary of the country of Bourke, this was therefore the stream surveyed. (See original plans, Lands Department, Melbourne.)

Reference to Figure 23 will show that Nussbaum's "characteristic longitudinal sections" place the main stream always at the lower grade, and, as explained by Hobbs (ref. 32) in the context: "Lateral streams, from the fact that they are tributaries, likewise descend upon somewhat steeper grades." If now we refer to the actual grades of the Werribee and its tributaries, we find a complex of apparent anomalies—each of which may be explained. (Plate XIIB). The point that might be stressed here, however, is that the "main or trunk stream"—the Upper Werribee—is everywhere at a higher level than the Lerderderg, and may be truthfully said to "flow into" the latter. It would seem that the commonsense way of really deciding a "trunk stream" would be to follow up the river from the mouth, and at each junction to select the stronger of the joining streams.

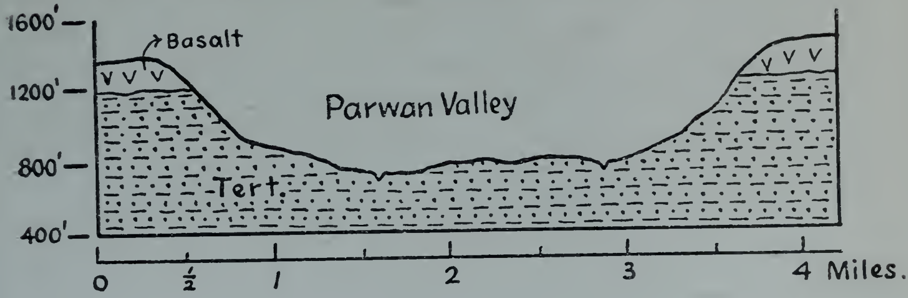
Speaking now of the Werribee as it is mapped and accepted, we shall consider its relations to the main tributaries. The Werribee flows south-easterly, receiving all its main tributaries from the north, with the single exception of the Parwan Creek (Plate XIIA., For the purpose of a clear understanding, these tributaries may be set out as under :—

Werribee	Northern Tributaries	Pyke's	Korjamumnip Korweinguboora Dale's . . . Back Korobeit
		Myrniong	
		Korkuperrimul	
		Lerderderg	Goodman's Clearwater Sargonne Allen's Split Tree, etc.
		Pyrete	
		Djerriwarrh	Boggy
		Toolam Toolern	Condon's
	Southern Tributaries	Parwan	Yaloak

The general directions of these tributaries are clearly set out on Plate XIIA., and need no further description. The interesting point of relationship is to be seen in their relative grades. Only the chief tributaries are plotted in Plate XIIB., since the addition of lesser ones would only add further complexity, without giving any additional information. It is at once apparent that the grades of the Werribee system, and their relationships depart very much from the "characteristic section" drawn in Fig. 23.

As already stated, the Lerderderg grade-line lies everywhere lower than the Werribee, except that for the last three miles before they junction, the grades are practically the same. This is in the Bacchus Marsh flats. The reason for the Lerderderg's lower levels are the greater age and the greater volume of that stream; it has been practically uninfluenced by the newer volcanic flows, and is for the greater part in the most elevated and most difficultly eroded block of land in the area.

While the Parwan is seen to grade into the Werribee in quite a normal way at the junction, its line crosses that of the latter about three and three-quarter miles up stream, and thence lies at a much lower level (500 feet lower in places), except where its extreme head waters grade rapidly up to the basalt plains. This is due to the fact that the course of the Parwan above the scarp is in extremely soft, level-bedded, tertiary sands, etc., with a thin basalt covering, while the Werribee was in hard, folded Ordovician, etc., also partly covered by a basaltic sheet. (See Fig. 24.)



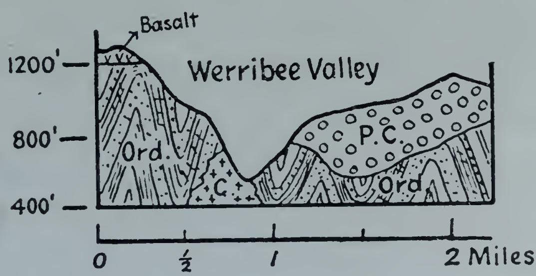


Fig. 24.—Sections across the valleys of the Parwan and Werribee valleys, at approximately equal distances above the scarp. To show the extent of the work of the Parwan in soft, level-bedded Tertiary sands and clays, compared to that done during the same period by the Werribee in the more resistant Ordovician, granite, and Permo-Carboniferous rocks.

It will be noted that Pyke's Creek, while it flows for a couple of miles at levels higher than those of the parallel Werribee, rapidly deepens, and for nearly four miles is much lower than the latter, entering at a gentler grade than that of the parent stream. The explanation is probably to be found in the fact that Pyke's Creek, with its many tributaries, has a larger catchment area than has the Werribee from their junction upwards. Pyke's Creek basin also lies for a good part of its course in more easily-eroded rocks—sandstones, decomposed older volcanics, and tuffs. It is no doubt from a consideration of the above facts that the site for a storage reservoir in this area was selected on Pyke's Creek. From a consideration of Plate XIIB we can also see how it has been possible for a tunnel to be dug, almost normal to the course of the Werribee, to lead its waters through the intervening higher area, into the Pyke's Creek Reservoir. When we come to consider the grades of the streams as a whole, we find remarkably fine evidence of the uplift and rejuvenation which have already been shown to have markedly affected the topography of the Werribee area. For purposes of comparison the profile of a rejuvenated stream (Lockajong River, N.J., U.S.A.), has been re-drawn from ref. 10 to the same scale as used for the Werribee (see Fig. 25). We see in this Locka-

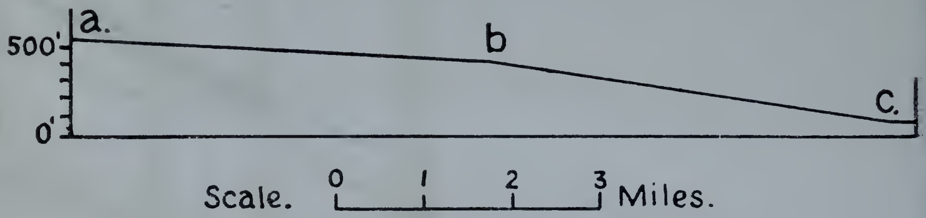


Fig. 25.—Profile of a rejuvenated stream. Lockajong River, N.J., U.S.A. (from Chamberlain and Salisbury) for comparison with the profiles shown in Plate XIIB.

jong river gradient that the characteristics of rejuvenation are shown by a gentle grade, a-b, a steeper grade, b-c (with gorges), and then once more a flatter grade from c onward.

This type of curve is strikingly shown in every river on Plate XIIA, with certain variations, which would naturally be expected, and which will be dealt with. In the lower reaches of the river a few small streams have been plotted. These flow over the volcanic plain, and then descend somewhat sharply into the steep gorge cut by the Werribee through those plains.

(iii.) *Details of the Individual Streams.*

(a) The Werribee.—This river is about 71 miles long. Its source lies on the Main Divide, near Mossop's Hill, Old Bullarto, and has been described. The course here lies in Ordovician rocks, and rapidly deepens. It is here mainly occupying an old valley that had been partly filled by a volcanic flow, but of which only remnants now remain. The gravels below these patches of basalt have been worked for alluvial gold. Musk Creek and Spargo Creek enter the river in steep-sided gullies from the east.

For the first six miles the Werribee flows south, parallel to the Eastern Moorabool. Just below the Greendale fault line it flows on to newer basalt, and thus continues past Ballan; the valley here is shallow and insignificant. It turns easterly at Ballan, and thence flows in a young V-shaped valley about 150 feet deep, cut into the volcanic plain. Between Ballan and its junction with Pyke's Creek, the bed exposes a variety of rocks such as might be expected hereabouts only in the Ballan sunkland: small patches of Ordovician sandstones, permo-carboniferous glacials, buried river gravels, etc. In several places it bisects deeper portions of the basalt, of which a better knowledge may some day give material for the mapping of the pre-basaltic river-beds there.

Where the river passes at the foot of Mt. Darriwill, a tunnel has been made to lead water through to the adjoining valley into the storage reservoir of Pyke's Creek. Half a mile or more before the Werribee joins Pyke's Creek, it has almost cut through a tongue of thicker basalt, giving a fine exposure of a pre-basaltic valley, cut in the underlying granodiorites. The present river course here is tortuous, probably due to meanders inherited from its original channel in the basalt plain, and exaggerated as the river deepened.

From Pyke's Creek downward, the grade is much steeper, cutting through the granodiorites and Ordovician beds on which it has been superimposed. These hard rocks have caused the river to give all its attention to downward erosion, and we pass into a precipitous gorge. For the next three miles, to the eastern end of "the Island," this gorge grows deeper, and here the steep-graded Myrniong Creek enters on the northern side.

From this point onward for about two and a-half miles, the river turns and twists through a gorge of great scenic beauty. The land on the left bank of this area, adjoining the river, has been proclaimed a public park. An excellent section showing the structure here has been prepared by Mr. C. C. Brittlebank, and published in the Monthly Progress Report of the Victorian Mines Department, May, 1899. Steep cliffs nearly 800 feet high occur, showing fine exposures of the great anticlines and synclines of the Ordovician, the junction of the latter with the granodiorite, old glacial valleys and striated "pavements," and many other features which combine to make this gorge an area greatly favoured by Victorian geologists. It has been described as "scientifically, the most famous place in Victoria."

On the south, a deep tributary comes in from the patch of bed-rock here exposed at the surface. This tributary, with its steep and densely timbered slopes, also provides some fine scenery, especially by contrast with the flat, uninteresting plains above. When the river emerges from the Ordovician, we come to the "mouth" of the Gorge, and in the softer rocks hereabout—mainly tertiary and decomposed older volcanics—the valley is wider and the land of greater economic value. A view near this point is shown in Fig. 26. The gentler slopes are lightly timbered, and rich river flats make their appearance. Past the residual basalt-capped Trig Hill, the Korkuperrimul Creek enters in a wide valley from the north, at a grade quite harmonious with that of the parent stream.

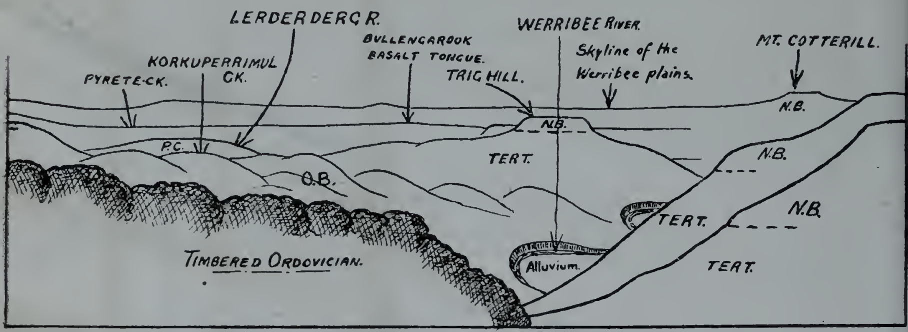


Fig. 26.—Sketch, looking east, of the view from the hills on the right bank of the Werribee River, below the Gorge. N.B.—Newer Basalts; Tert.—Tertiary sandstones, etc.; O.B.—Older Basalts; P.C.—Permo Carboniferous sandstones, etc.

We here pass the line of the Rowsley fault, and a small let-down tongue of lava crosses the river coming from Bald Hill. This causes a narrowing of the valley (see Fig. 38). Beyond that the river valley widens out into the fertile flats of the Bachus Marsh basin, through the alluvial of which it runs in a channel 10-20 feet deep. As is usual with such flood plain deposits, the levels of the "flats" slope away from the river for some little distance.

The structure and origin of this basin is discussed later. Towards the further end of this area, the Parwan enters from the south, and the Lerderderg River from the north, with the Pyrete Creek coming in from the north a quarter of a mile further on. The Werribee then leaves the flats, and swerves to the south, entering once more a young, narrow valley cut into the basalts (see Fig. 38). From this point onward the river flows generally south-east, across the plains, to the sea. A little over two miles along this narrow gorge the Djerriwarrh enters from the north, at a low accordant grade.

A mile and a-half further, the Melbourne-Ballarat railway crosses the Werribee, at a point where a small unnamed tributary valley

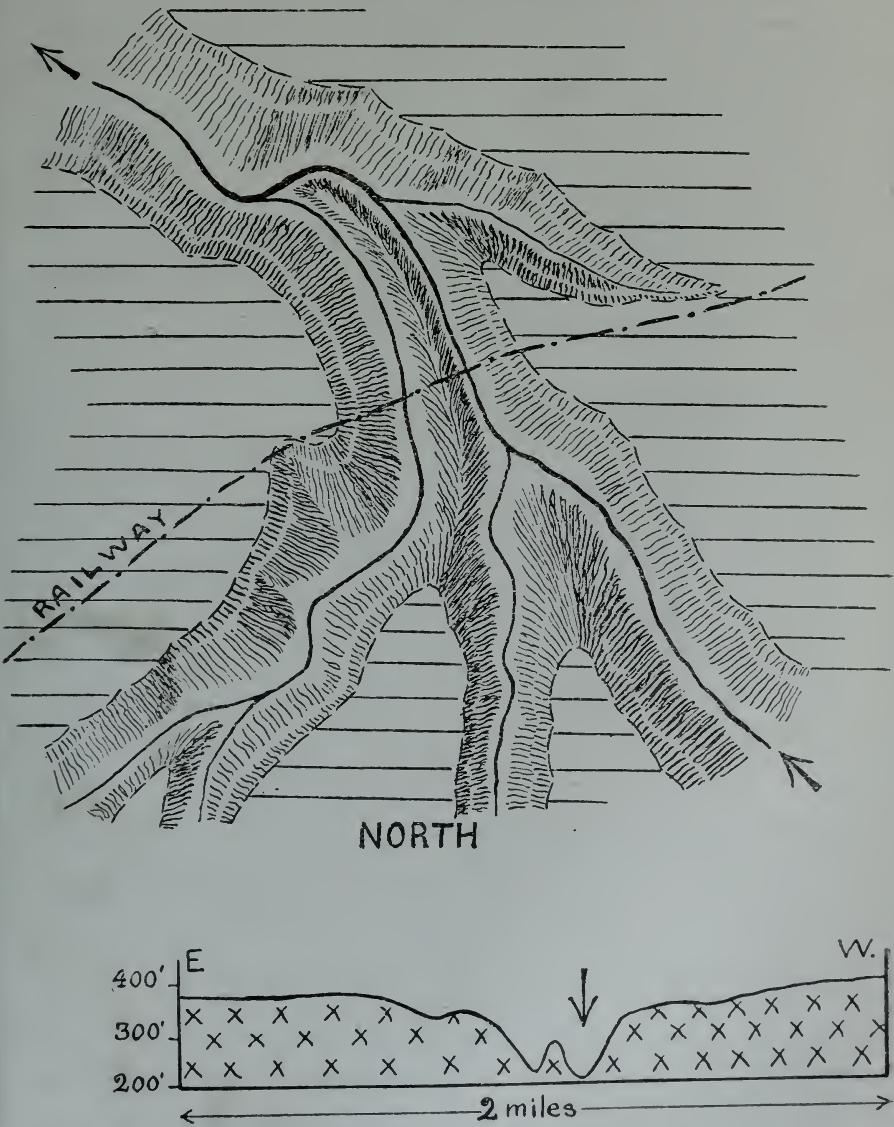


Fig. 27.—Junction of small stream with the Werribee River in the basalt plains near Melton. The Werribee is indicated by arrows. This shows also typical plan and section of the narrow valley of the Werribee in these plains.

enters from the north. This junction presents features of some interest, and has often been remarked by travellers with an eye for topographical features. Both the Werribee and the small tributary valley are in basalt, but the tributary delays its entrance in a peculiar way, running parallel to the main stream for some little distance. A plan and section of the junction is shown in Fig. 27. The bed of the Werribee is here 160 feet below the general surface level of the basalt plain. This feature has been erroneously referred to (Vic. Handbook, B.A.A.S., 1914), as a "deserted creek bed."

An iron viaduct, 1130 feet long, here spans the Werribee, the foundations for this structure penetrate deeply into "alternating beds of sand, gravel, clay, and lignite," which underlie the basalt. For the greater part of the year, the waters of the new storage reservoir at Exford now submerge the feature described in this paragraph.

Three miles further down stream, at Exford, the Toolern Creek enters from the north, at an accordant grade. The erosion about this junction has given gentler slopes to the sides of the valley, and three roads meet here to cross the river. Immediately above the junction is the site of the Exford reservoir; from the nature of the valley the stored water will be contained in a very long and narrow dam, reaching upstream for several miles. For the remainder of its course (twenty-four miles) the river receives no tributaries, flowing evenly along in a young valley averaging 150 feet in depth. At the town of Werribee, where the Geelong-Melbourne road and railway cross the river, it enters a triangular area of river gravels and dark-coloured alluvium, though which it cuts its channel to the sea. The appearance of the mouth was roughly compared with a survey of fifty-five years ago; it is very slightly different at the present day. (See Quarter Sheet 20, S.E.) Just as we found rich farms at the very source of the stream, seventy-one miles away, and 2400 feet higher, on the top of the Main Divide, so here at the mouth the land is irrigated and cultivated to the very edge of Port Phillip Bay.

(b) *The Lerderderg River.*—The source of this river in the Main Divide has already been described. It is close to, and at the same level as, the source of the Werribee, separated therefrom by a low ridge. Erosion in the cultivated land of its extreme upper reaches is rapid, and the loose chocolate soil is being fast carried away. Springs from beneath the basalt provide excellent water, and are permanent. The Lerderderg valley deepens rapidly, and as one stands at the source and looks down stream, the river is seen to pass into a wide, deep, thickly-timbered, uninhabited valley carved out in the Ordovician rocks of the uplifted peneplain. As before stated, the Lerderderg, down to the point where it crosses the Rowsley Fault, is an old river rejuvenated; one may detect a valley-in-valley structure at various points, and there seems no doubt that this river was one of those that in early to middle tertiary times completed an erosion cycle by the formation of the peneplain. The Lerderderg here receives tributaries from the south and north, and the valley appears quite basin-like, narrowing in as it rounds the southern side of Mt. Wilson—an important residual range. The river then flows east and south-east through the mining township of Blackwood. Terraces of auriferous allu-

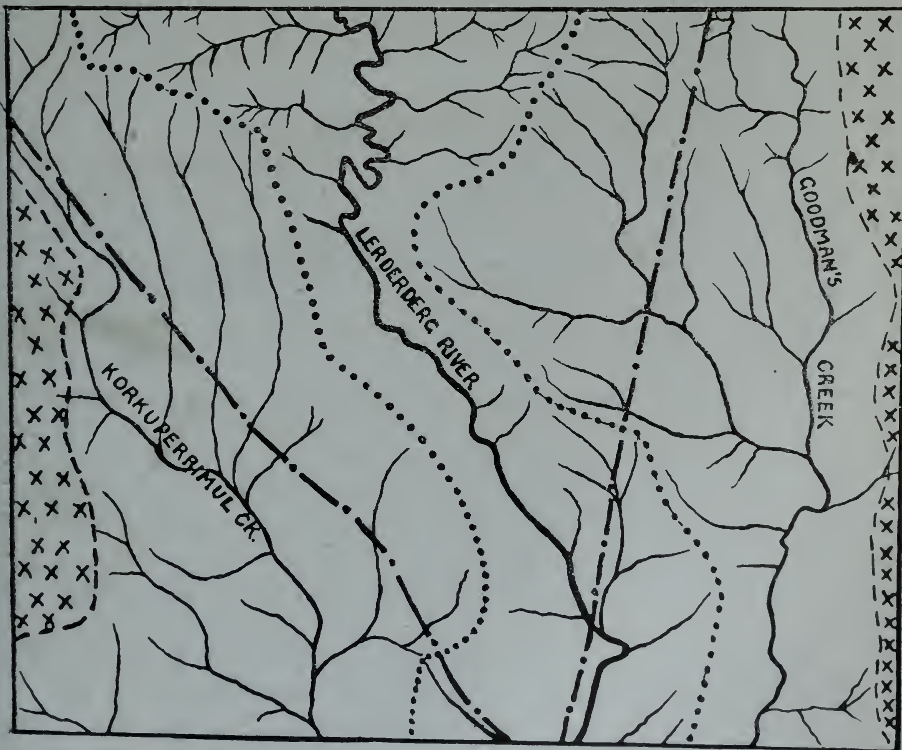


Fig. 28.—Plan showing probable captures from the Lerderderg River. The thick, broken lines represent prominent Fault Scarps. Tributaries of the Korkuperrimul and Goodman's Creeks, working back from these scarps, have entirely robbed the Lerderderg here. Within the triangle formed by the fault scarps, the rocks are hard ordovician slates, through which the Lerderderg flows. The part marked with crosses represents basaltic flows.

vial remain in places along the valley sides, at varying distances above the present bed. At Blackwood, the river cuts right across the strike of the almost vertical beds, exposing anticlines and synclines. It is believed by Blackwood miners that the course of the river is here directed by a large east-west dyke. As the river trends south-easterly through the ranges, with many loops and meanders, its valley is over 800 feet deep, with precipices 500 feet sheer in places. From the summit of Mt. Blackwood its valley may be traced through the Ranges, completely bisecting the uplifted peneplain; beyond, we may see where it opens out on to the flat country below the Rowsley Fault scarp.

The last few miles of the Lerderderg gorge are reproduced in plan in Fig. 28, showing how the neighbouring creeks have robbed the Lerderderg of its territory. One may note here the extreme narrowness of the area drained by the Lerderderg; the sketch shows the positions of the Korkuperrimul and Goodman's Creeks, both of which, working largely in soft glacial sandstones, appear to have enlarged their basins at the expense of the Lerderderg.

Immediately the fault line is crossed, the river passes from a young stage, with a valley 1000 feet in depth, to the stage of an old river meandering across a flood plain, and with numerous terraces. At the northern end of the Lerderderg flats, near Kerr's farm, a pretty series of terraces occurs, as reproduced in Fig. 29, from a notebook sketch. The "meander belt" here is bounded by two cliffs of hard glacial conglomerate C_1 and C_2. Compared with an ideal terrace series it will be seen that a peculiar restriction occurs; while normal down-stream "sweeping" is observable in terraces 1, 2, and 3 on left bank, this has been restricted on the right bank by a hard cliff of glacial material at X. This section at X is also instructive insofar as it exposes evidence of a now buried terrace series, cut into the old glacial beds. These terraces are worthy of a more detailed study than the writer was able to give.

Just above this point, the interesting tributary of Robertson's Creek enters the Lerderderg. It has a very steep grade, and has built up a fan delta where it enters the larger valley. Its course lies mainly along a fault junction—the eastern end of the Greendale fault. It is vigorously cutting into the older basalts, glacials, etc., of its right bank; the left bank is Ordovician. It appears to be about to capture the head valleys of a small Korkuperrimul tributary; and apparently even now receives some water from that stream during heavy rains.

As the Lerderderg flows on through the "flats," it is bounded, at some distance, on the right bank by the treeless, residual ridge of Bald Hill (glacial and older basalts) and on the left bank by the sands and clays of the tertiaries, overlain by the tongue of newer

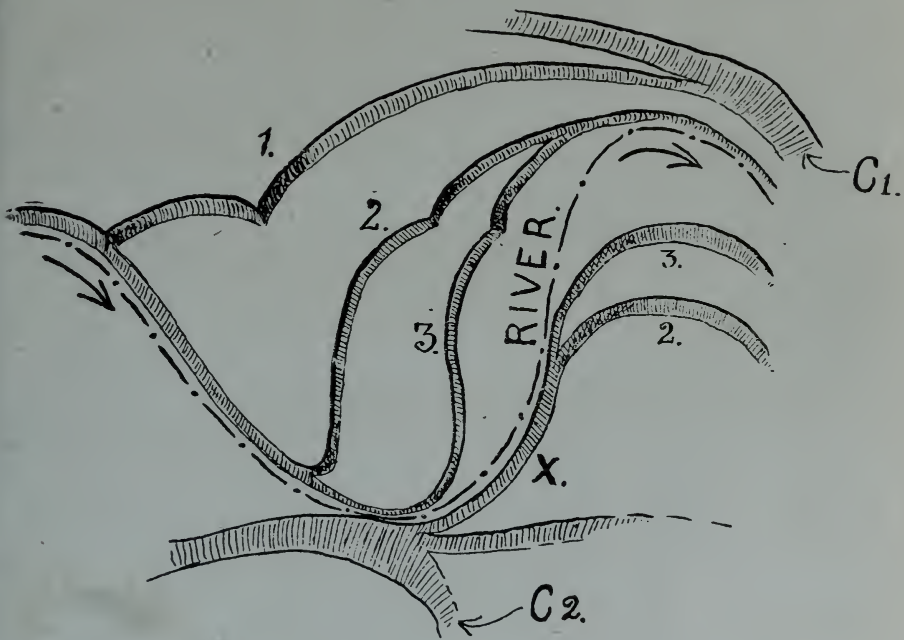


Fig. 29.—Plan of terraces on the Lerderderg River, near Kerr's farm, above Darley.

basalt that filled the "Ancient Bullengarook" Creek. Ordovician is exposed in the bed of the creek at the Darley Bridge. An important tributary, Goodman's Creek, coming from the north, enters about a mile above this bridge. While this part of the river is referred to above as "older" than the upper Lerderderg, it is of course only so in form. As a matter of fact this mature valley, in soft rocks, is post newer basaltic in age, and from the point of view of time, much later in origin than the portion of the valley in the ranges. From Robertson's Creek, right down to the town of Bacchus Marsh, the western side of the valley, between the present bed and the Bald Hills, is covered by thick terraced deposits of coarse pebbly alluvial, standing at high levels. For the last mile of its course, the river runs parallel with the Werribee, in a similar channel, in deep alluvium, and joins that stream near the eastern end of the Bacchus Marsh basin.

(c) *The Parwan and Yaloak Creeks.*—The Parwan, with its tributary Yaloak, is the only tributary of any note to the south of the Werribee. Its upper valley is very impressive, especially when

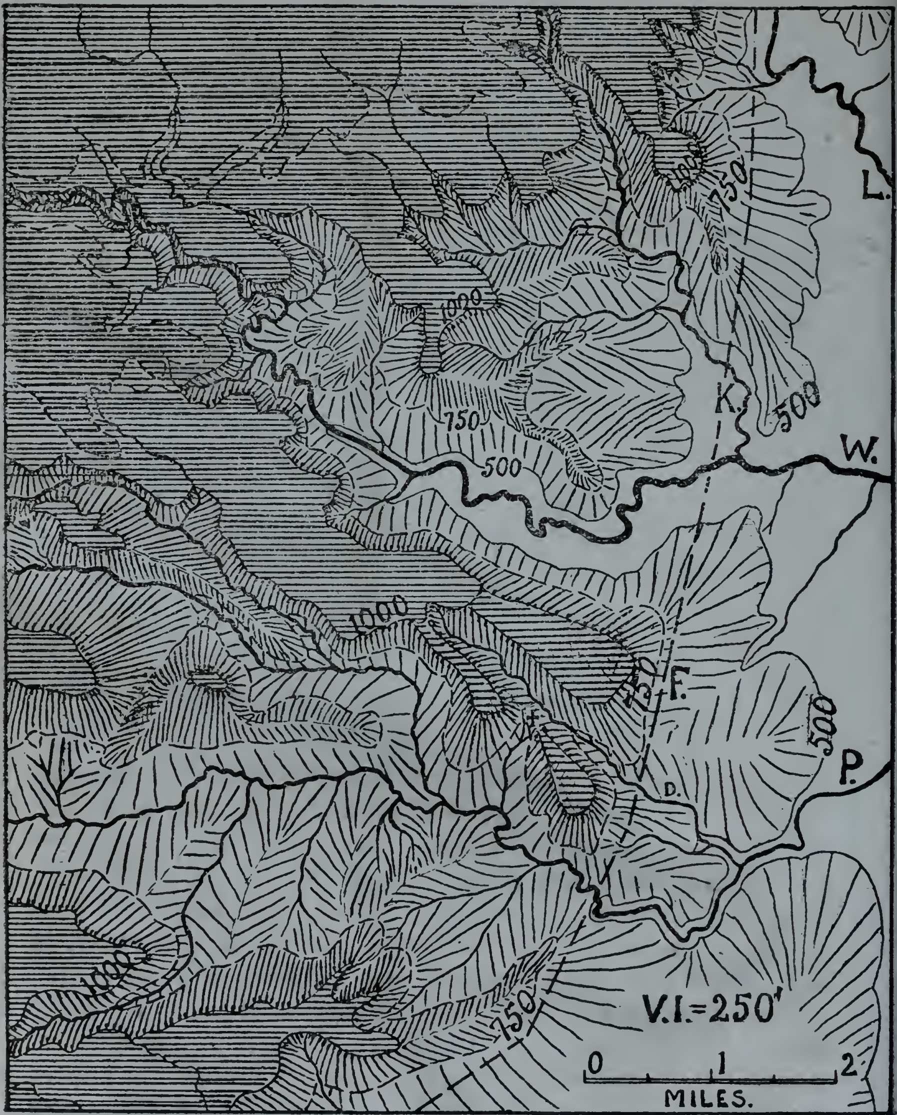


Fig. 30.—Differential erosion of the Rowsley Scarp at Bacchus Marsh, 250-foot contour intervals. The original line of the scarp is marked F. L.—Lerderderg; W—Werribee; P—Parwan; K—Korkuperrimul. This is the most deeply eroded portion of the scarp.

we consider the size of the creek which carved it out. It is a great irregular basin, four miles across, about eight miles in length, and 800 feet deep, descending sharply from the surrounding newer volcanic plains. Except for the last five or six miles from the edge of the scarp to the Werribee, the Parwan lies wholly in this basin. It is a small stream at best, and is dry for a large part of the year. The amount of arosive work accomplished is therefore all the more astounding, and is indicated to some extent in plan (Fig. 30), and in section (Fig. 24).

This plan (Fig. 30) is drawn to indicate the amount and nature of dissection of the fault scarp in the neighbourhood of Bacchus Marsh. It also indicates the differential erosion due to differences of rock structure, and this is again shown in the two sections chosen (Fig. 24). The smaller stream (Parwan Creek) has carved a valley of the dimensions indicated, while the much more powerful Werribee has carved out the well-known "Gorge." Both streams are here exactly the same age; but while the Werribee worked, as already indicated, in very resistant rocks, cutting mainly across the strike of hard Ordivician sediments, the Parwan had the advantage of a location in level-bedded, uncompacted tertiary materials; in both cases there was a covering sheet of newer volcanic. Landslips play a great part in the enlargement of the Parwan basin, and their influence is seen in the steep, broken, lumpy, white-streaked, unstable valley slopes. Residual ridges and hills occur within the valley, some of them capped with basalt which stands at a lower level than that of the plain. Such

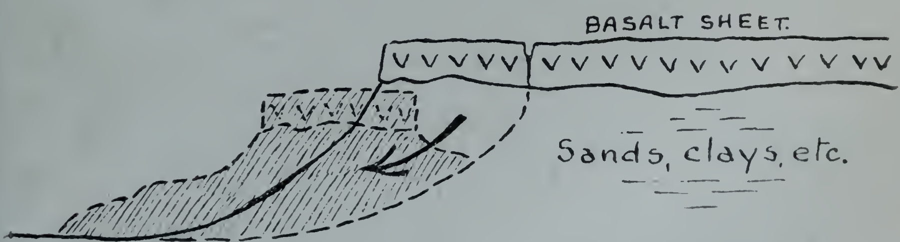


Fig. 31.—Diagram to indicate the possible mode of formation of certain hills in the Parwan valley.

cases possibly represent land-slipping on a large scale. A large mass of basalt, with the thick underlying tertiaries rendered unstable by a thorough soaking during an extra-wet season, has "slumped" boldly into the valley, as suggested by the shaded portion in Fig. 31. The head waters of the Parwan and Yaloak Creeks are still vigorously cutting back, as shown in Fig. 37. Spring Creek, a southern tributary, flows partly along the junction between the tertiaries and the Ordovician; it has a deep narrow valley, already referred to.

Just within the basin a valley enters from the north, and was carefully examined on account of the possibility of a small capture. The locality is shown in plan in Fig. 30. It will be seen that the last left bank tributary of the Parwan has cut back to the Dog Trap Gully, and only a ridge of soft, white clay separates the two streams. Very little perceptible change has taken place in the past fifty years. In the lower part of the stream some small ravines are cutting back. Capture will no doubt take place at this point in time, since the Parwan tributary has a steeper grade and has no basalt to impede its downward cutting. The Dog Trap Gully is flowing along the side of an old basalt-filled river, and in places basalt still occurs in its bed. An interesting relic of earlier days was found on the ridge at the head of this tributary, where hundreds of chipped flakes of flint, chert, quartzite, etc., testified to an old aboriginal camping place.

An observer standing at the bridge some little distance within the wide Parwan basin, would have difficulty in discovering the outlet of the Parwan, as the basin appears to be completely surrounded by hills. On the right bank of this creek an interesting hill occurs (ref. 56, note 16). This is represented in Fig. 32. The

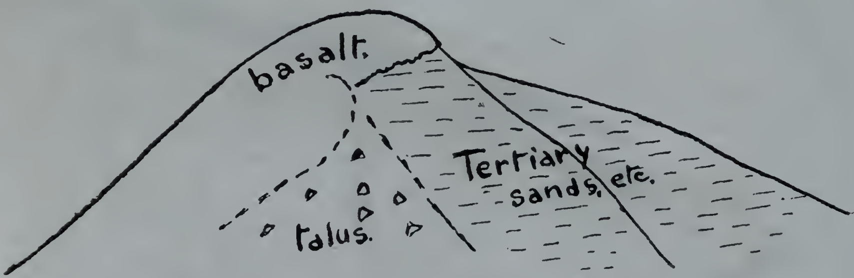


Fig. 32.—Sketch of ridge at the right of the point where the Parwan Creek crosses the line of the Rowsley Fault.

basalt in places is ropy in structnre, and the evidence here taken alone would perhaps suggest that the lava had flowed over a low scarp. This is, however, negatived by other observations, as already pointed out in section VIII. (b).

Just before leaving this basin the river meanders a good deal through irrigable flats, and then passes out through a narrow gut in the basalt, thus leaving the scarp. Thence to the Werribee, the Parwan flows north-east across the basalt sheet, which it has cut through in its lower part, exposing the tertiary beds below. The last couple of miles are across river flats, and the Parwan then enters the Werribee not far from the junction of the latter with the Lerderderg.

(d) *Pyke's Creek.*—This creek is marked in most maps as the Korjamumnip, but locally it is called Pyke's Creek in the lower part, after one of the early settlers. It has as tributaries the Korjamumnip, Korweinguboora, Dale's, and Korobeit Creeks—all of which have their origin in the high block north of the Greendale fault, along an easterly ridge that runs from near Blakeville to Mt. Blackwood (see Fig. 18). Their valleys probably originated subsequently to the Greendale uplift, due to the cutting back of small streams into the scarp face. As they proceeded thus they probably occupied some of the southern territory of the ancient Lerderderg, The influence of the rock structure of the Ordovician beds is shown in all these streams, but more clearly in the case of the Back Creek, which will be considered later.

The Korweinguboora Creek rises near Blakeville, and does not now occupy its original valley, which was basalt filled during the newer volcanic period. Just before leaving the ranges, it occupies a deep gorge between this newer basalt tongue and the Ordovician. (Fig. 8.) On emerging from the ranges the river turns eastward along the line of the Greendale fault for about a mile, with a high steep scarp of Ordovician on the left bank, and thick, but much lower, deposits of older basalt on the right. It then turns south into the older basalt, in a gently rounded valley, almost treeless, but well grassed, and a mile from the scarp it joins the Korjamumnip.

Tht Korjamumnip Creek flows southward from its origin in the ridge mentioned, in a steep, timbered valley. Among its numerous tributaries in the ranges is the Green Hills Creek, a small stream rejuvenated by a basalt flow. Steep valleys continue to the edge of the scarp, where, like the Korweinguboora, this stream also turns eastward along the fault line, and then south through the older basalts. The distinct nature of the valleys of all these streams after crossing the Greendale fault is very marked. Above the fault the valleys are over 500 feet deep, narrow, and V-shaped; immediately below they are at most 150 feet deep, wide and U-shaped. There is also the important differences of rocks and soils above and below the fault, already pointed out in other sections. The Korjamumnip flows south through older basalts and glacial sandstones as far as the Ballan-Greendale road, when a marked change is noted. The influence of the newer volcanic sheet is apparent, and the valley is much deeper and narrower. It is here known as Doctor's Creek. Landslips are very common along the steep slopes, in the decomposed and "greasy" older basaltic material that underlies the newer basalt. Beyond "Highton" the creek turns east, and receives Dale's Creek coming in a similar valley from the north. A mile and a half further the Korobelt Creek comes in from the east, and here the Pyke's Creek reservoir has been built, where the Melbourne-Ballarat road crosses the valley.

Thence onward the Pyke's Creek has a deep gorge cut into soft tertiaries, hard glacials, and still harder granites and Ordovician, to the junction with the Werribee. As shown in the profile diagram (Plate XIIA.), the lower part of Pyke's Creek is much deeper than the parent Werribee, the possible reasons for which have already been advanced.

Dale's Creek flows south from near Green Hills, in the northern ranges. Near its head the valley is wide and shallow, but rapidly deepens. Just before reaching the scarp, it suddenly turns eastward, leaving thick deposits of coarse fan delta material piled up near the face of the scarp (eastern part of Garibaldi Hill). This easterly turn may possibly be ascribed to capture by another small stream that had cut back from the scarp face and got into the soft material of an E.-W. dyke, such as are known to abound in the area. Where Dale's Creek now crosses the fault line, it passes into glacial sandstones, and the contrast in the appearances of the valley above and below the fault is even more marked than in the cases already mentioned. A wide dyke marks the creek-bed juncton between the Ordovician and glacials. Thence to "Glenpedder," the valley is wholly in glacial sandstones, with small flats, and bounded by the rounded, grassy hills which mark the village of Greendale. Opposite "Glenpedder" homestead a high cliff occurs in the glacial conglomerates; below, as far as the junction with Pyke's Creek, the valley is in older basalt, with gently sloping sides.

Back Creek is mostly in the ranges, since it joins Dale's Creek less than a mile below the Greendale scarp. Messrs. P. B. Nye and B. Liston, who surveyed this small stream, were continually struck by the prevalence of almost right-angled junctions between N.-S. and E.-W. valleys. The strike of the rocks is almost due

N.-S., and E.-W. dykes are numerous, some having been located at the points where E.-W. valleys join the main stream. It is natural to infer that the structure of the rocks has very greatly influenced this creek, especially as regards its N.-S. and E.-W. valleys. It would appear from Fig. 33 that a second series of fractures has also influenced the stream, running about east 47°N.,

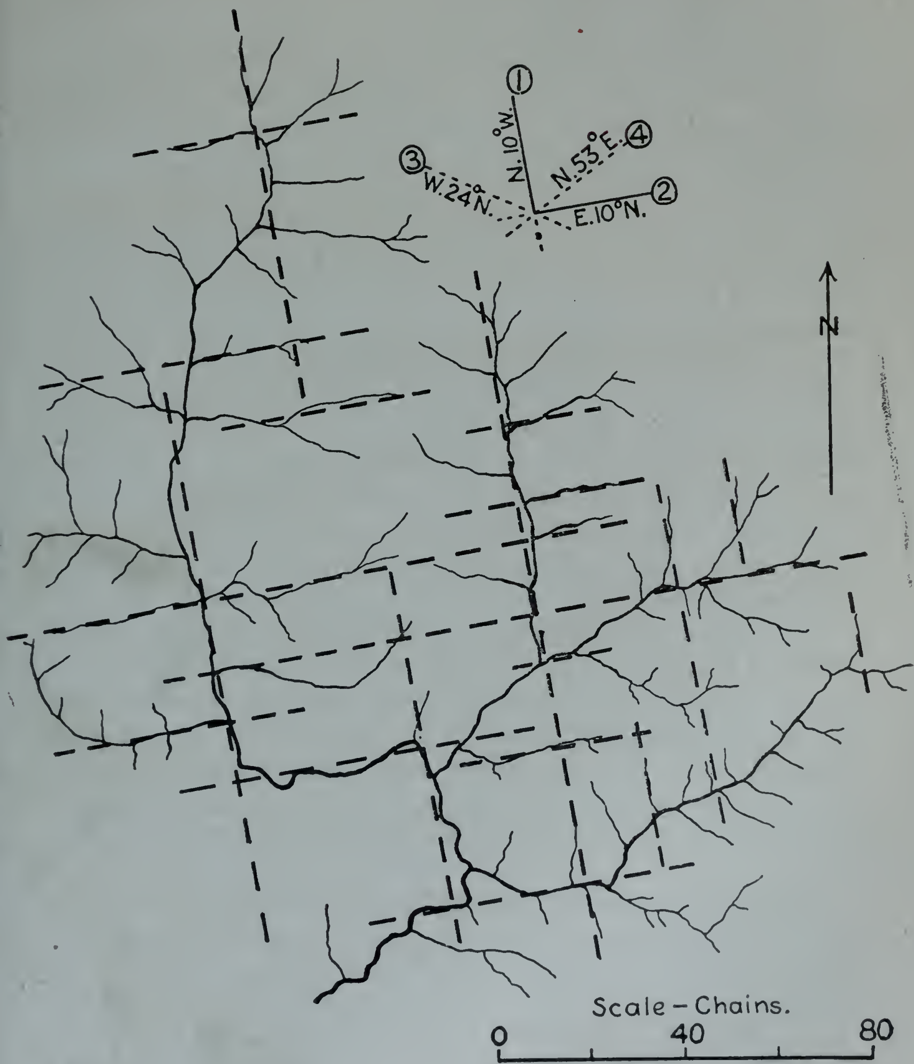


Fig. 33.—"Drainage Network," of Back Creek, Greendale, showing the possible influence of the rock structure of the lower ordovician rocks through which it flows. The strike of these rocks is approximately North, and East-West dykes and fractures are numerous.

and east 24°S. No evidence for this was especially looked for in the field, but Hobbs (ref. 32, p. 56) suggests that the "master-joints" of a crushed block are intersected by another set at about 45° to the first. (See also Fig. 242, ref. 32, the "pattern" of the stream shown in Hobb's figure has a peculiar resemblance to that of Back Creek).

Korobeit Creek rises near Mt. Blackwood, and has been influenced in its upper parts by the Blackwood basalts. It flows south and west through Ordovician, later tertiary gravels, and older volcanics (including tuffs), in a wide valley that was perhaps already chosen in pre-newer basaltic times, joining Pyke's Creek at the reservoir. This concludes the account of Pyke's Creek and its tributaries.

(e) *Myrniong Creek.*—This stream is wholly post-newer basaltic. Its ancestor, the "ancient Myrniong," flowed down from where Mt. Blackwood now is, entering the "ancient Werribee" not far from the point where the Myrniong junctions with the present Werribee This old valley was filled by a newer basalt flow (Fig. 21), and the "twin streams" of the Myrniong and Korkuperrimul Creeks arose one on either side. The head valleys of the Myrniong are in Ordovician rocks, and are at first somewhat steep, but soon widen out. The stream flows south, keeping the lava flow of Mt. Blackwood on its eastern bank, and with a variety of older rocks on its western side. At the village of Myrniong, in response to a western bend in the basalt tongue, it also turns westward, and then south. It then enters granitic rocks, which being much decomposed are here, less resistant than the newer basalts. About a mile south of Myrniong it cuts an old basalt-filled river-bed, and thence continues flowing directly towards the Werribee. A little distance further along the stream again meets a deeper tongue of basalt, filling an old valley in the granite, and this gives rise to a most peculiar, though small, physiographic feature, shown in Fig. 34.

This peculiar loop in the Myrniong occurs where it comes in contact with the basalt, which it has not yet quite cut through. It takes a long course through this basalt, doubling right back on itself as shown in the figure. High cliffs occur where the hachures art darkest. The country rock here is granitic, and just over a low ridge, a few hundred yards from the southernmost point of the loop, is the gorge of the Werribee, 300 or more feet deeper. Why the Myrniong chose to turn here, across this very resistant obstruction, and to flow to the Werribee in the present long loop-like course, is difficult to say. It would have been much easier and

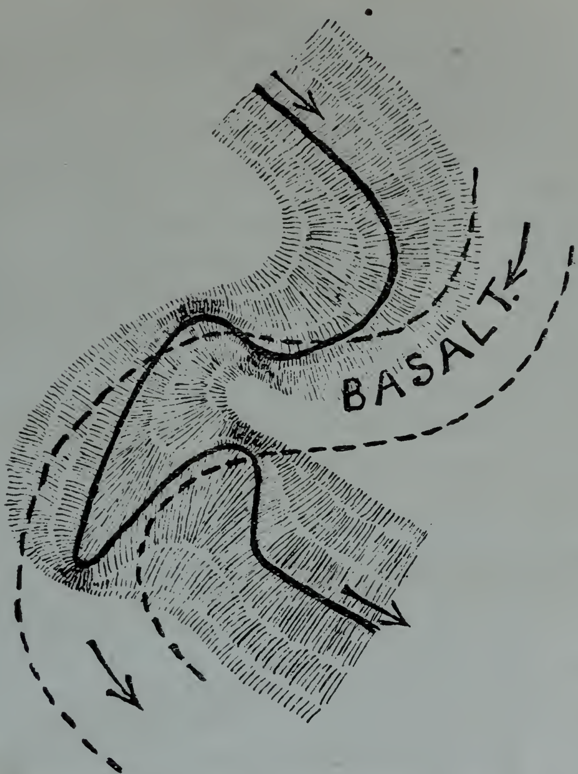


Fig. 34.—Plan of an interesting, though minor, physiographic feature on the Myrniong Creek, where a bar of basalt, filling an old stream valley, crosses the present stream course. Outside the basalt, the rock is granodiorite. Below this bar the grade of the Myrniong steepens rapidly.

more direct for the Myrniong to have continued straight on to the Werribee without cutting through the obstructing basalt. There are two possible answers to the question. Firstly, the basalt sheet may then have been much more extensive, and the Myrniong, flowing on that sheet, might have been pledged to its present course before it had cut down and "discovered" the present obstruction. Or, secondly, and more probably, the Myrniong really did once, in its early days, flow direct into the Werribee at the place mentioned, and was captured by the headward erosion of a small stream, which may have entered the Werribee below the resistant basalt bar that once crossed the latter stream near the eastern end of "the Island." After crossing this bar, the Myrniong runs eastward, looping round "the Island," and entering the Werribee. For this part of its course the valley is very young and steep-sided, with a grade of over 400 feet to the mile. The effect of the obstructing basalt bar is very noticeable in the grades of the Myrniong—above that bar the fall is 100 feet to the mile, below it is over 400 feet to the mile.

(f) *Korkuperrimul Creek.*—The upper part of this creek is exactly similar in age and origin to the Myrniong Creek. It flows south for about three miles in Ordovician, with basalt on the right, and high Ordovician on the left. It then turns south-easterly, possibly following the line of the Greendale fault. Into a let-down block of glacial south of this line, the Korkuperrimul then turns its course, and so in a gradually widening valley, and with a gradually lessening grade, it passes through glacial sandstones, older volcanics, and tertiary beds to the Werribee.

That part of the Korkuperrimul that lies wholly in the older basalt is quite steep sided; the characteristic contours are represented in Fig. 10.

The Korkuperrimul, as elsewhere stated, has captured some of the Lerderderg territory. Morton's Creek, flowing in a wide valley through older basalts, and entering the Korkuperrimul on its right bank, is the chief tributary. The last mile of the Korkuperrimul, past Bald Hill, is approximately along the line of the Rowsley Fault, but that feature is now quite obliterated in the extensive erosion of the soft rocks there (See Fig. 30.)

(g) *Goodman's Creek.*—This long and important south-flowing tributary of the Lerderderg must, from the point of view of origin, be considered in conjunction with its "twin stream"—the Pyrete Creek. The area now drained by these two streams was originally the territory of the ancient Bullengarook Creek. When the latter stream was filled by basalt, the two creeks under discussion arose, one on either side. There they have entrenched themselves in deep valleys, with the lava tongue now standing high up between them.

Fig. 16 depicts the origin of such a pair of streams; the facts are of course well-known, but the diagram is intended to give definiteness to the idea. A shows a stream, with a cross-section of its valley. B represents this stream valley, its lower parts filled by a lava flow. In C two "twin streams" have commenced their work, and a further stage is shown in D. It will be noted that both valleys must typically receive their longest tributaries on the sides remote from the flow; this is very distinctly and characteristically seen in the case of Goodman's and Pyrete Creeks. In some cases of course, one stream may for some reason desert the side of the flow, as the Korkuperrimul has done; or one stream may flow right across the lava tongue, as has happened in the case of Turritable and Willimigongong Creeks at Mt. Macedon. The ultimate result must of course be the total destruction of the lava tongue, with the possible formation of one stream again, but such a stream should itself have a characteristic shape that would indicate its mode of origin. Possibly none of the post-newer basaltic streams in Victoria have yet reached that stage.

Goodman's Creek has a fairly steep and even grade; it flows mainly in Ordovician, parallel to and below the northern continuation of the Rowsley fault. A long, high scarp of tree-covered Ordovician hills bounds the western side of Goodman's Creek, while the Bullengarook basalt limits the eastern side of its valley. A large number of important tributaries come down from the western ranges; a few very steep gullies enter on the east. The lowest of the three western tributaries shown in Plate XII.B flows, in its W.-E. portion, along the Coimadai fault, between Ordovician and glacial. For the remaining two miles of its course, to its junction with the Lerderderg, Goodman's Creek lies in glacial rocks, in a wide valley, with gentle grades.

(h) *Pyrete Creek.*—This is also known as Coimadai Creek. It rises in the deeply ravined block of high Ordovician east of Mt. Bullengarook. The tributaries that lie in these ranges are pre-newer basaltic in age, with the possible exception of subsequent minor captures, and no doubt belonged to the ancient Bullengarook Creek. The main part of the river is, however, post-newer basaltic, as already described. A vigorous attack is being made on the lava tongue where it bends westward, and the old river gravels are here exposed in three places; where seen these gravels are iron-cemented and very coarse. The extensive "bight" in the Bullengarook basalt tongue (Fig. 22) does not represent the original outline of the flow at that point, but is mainly due to the erosive work of the Pyrete Creek. The river is in Ordovician as far south as the village of Coimadai; here it crosses a small fault (see Fig. 5), and enters on an area of glacial sandstones and conglomerates, and tertiary limestones and clays. It occasionally cuts through these to the Ordovician bedrock beneath, exposing in places the beautifully striated permo-carboniferous glacial pavements described by Officer and Hogg (ref. 43), etc. For the last few miles the river has cut through the newer basalt and tertiaries, exposing low-level Ordovician slates. It finally enters the Bacchus Marsh basin and flows across the alluvial flats to the Werribee. The grade of this creek, as plotted in Plate XIIA., shows traces of two "breaks," with steeper grades, apparently due to the two E.-W. faults that lie in its course.

(i.) *Djerriwarrh and Toolern Creeks.*—These two streams did not receive the close attention given to other streams described. The Djerriwarrh is locally known as Deep Creek, and the Toolern is shown in some maps as the Toolam Toolern. The Djerriwarrh receives a fairly important tributary—Boggy Creek—on its right, while the Toolern receives Condon's Creek (sometimes called Yangardook Creek) on its left. Their grades, as shown in Plate XIIA., and their general appearance in the field, bear witness to rejuvenation in their upper portions. In this rejuvenation differential uplift and lava flows have each played a part.

The Djerriwarrh Creek lies wholly in Ordovician, except where its extreme upper tribuaries flow over the Gisborne basalts. Its profile (see Plate XIIA.), indicates that while it is wholly in Ordovician rocks, as far as known, yet these rocks stand at two distinct levels; this profile has been already used as evidence in favour of a fault junction separating the higher deeply-dissected Ordovician, from the low relief area to the south. On the evidence of the contour maps, and without having personally examined that particular portion of its course, the writer would point out the high possibility of the head gullies of the Djerriwarrh Creek having been captured by the Pyrete Creek.

The Toolern Creek in its head gullies has partly cut through the basalts to the Ordovician bedrock, but the greater part of its course lies on the newer volcanics. The writer travelled along it, but found no features of particular interest. Where it passes through the township of Melton, on the Melbourne-Ballarat road, its valley is scarcely perceptible, but it rapidly deepens after crossing the railway line, and enters the Werribee at Exford in a steep-sided valley, wholly basaltic.

(iv.) *The Buried Rivers.* (*Pre-Newer-basaltic.*)

We have no means of discovering the nature of these old river courses beneath the volcanic plains of the Port Phillip sunkland. The bores put down in and near the township of Melton suggest that "deeper ground" exists from the Djerriwarrh Creek towards the Toolern Creek, but the sub-basaltic area here was evidently of very low relief, with widespread gravels and clays; and no definite valleys were detected. Bores and shafts at Altona Bay and Newport show that, under the basalt, there are hundreds of feet of tertiary material, marine and fluviatile, with bedrock at about 400 to 500 feet. At Lara, towards the southern end of the plains, a bore passed through 376 feet of gravels, limestones and clays of tertiary origin. The general level nature of these volcanic plains, except where interrupted by the very ancient residuals of the You Yangs and Anakies, suggests that the underlying surface was also of very low relief, while the evidence of the bores, etc., testify that this surface was composed mainly of marine and estuarine materials (tertiary).

The writer visited the "basalt caves" south of the Parwan railway station. These as far as explored were wholly in basalt, and were formed by the collapse of basalt blocks into some older cavern. It may be that this older cavern was an "inter-basaltic cave," formed by the flowing away of the molten interior after the outer parts had cooled; or it may be that, as at Mt. Mary, limestones occur below, in which underground waters have dissolved out a cavern, and into this some of the overlying basalt has subsequently collapsed. No positive evidence was to be seen in favour of either hypothesis. This is the sum of our knowledge concerning the buried river system of the Lower Werribee plains. This area is therefore left out of our present considerations.

The Blackwood Ranges have been shown to be but slightly affected by the newer volcanic sheet, and that area, too, may be largely left out for the present. We have to consider, then, the central part of the area, containing the main plexus of this river system, as it is drawn in Fig. 35. On this is set out all we have learnt concerning the ages of the present day rivers and creeks, as detailed in the preceding pages. It will be seen that the great majority of the present streams are, without doubt, wholly post-newer basaltic; their present valleys being cut through that rock. These are shown by dotted lines.

In a few cases it is doubtful whether or not the courses were established prior to the newer basalts; such streams are put in with dots and dashes, and thus they must be left until some evidence is found. In yet a third series, the present river courses are still almost the same as were established in pre-newer basaltic times, and are marked with an unbroken line of arrows. These last-mentioned streams indicate something of the trend of the old drainage system; the Lerderderg strongly suggests that the main slope here lay south-easterly.

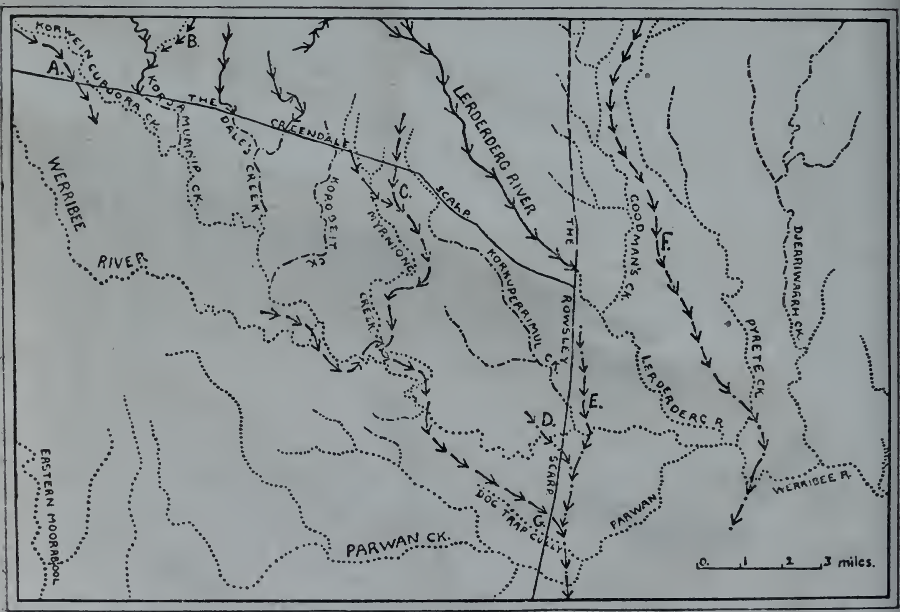
Our work lies now in those areas where newer volcanic rocks at present occur. In endeavouring to find out the secrets of the rivers hidden there we may adopt two different methods, according to the nature of the basalt distribution :—

(1) If the basalt is discontinuous, occurring in long tongues, it may and practically always does mark the course of an ancient valley.

(2) If the basalt is a wide sheet, we may search in our present river gorges and cuttings for exposed sections of the buried valleys.

The first method is very simple, and many references have already been made in this paper to the old valleys thus disclosed. These instances will be briefly recapitulated, with reference to Fig. 35, and some fresh cases added.

It may be stated that a lava flow, now almost destroyed, accompanied the upper part of the present Werribee, at least to a point parallel with Egan's Hill. Thus the upper Werribee was also the site of a pre-basaltic valley. While the basalt referred to in this paragraph, as well as much of that towards the village of Korweinguboora, is usually regarded as belonging to the "newer



PRESENT RIVER COURSES: a. developed prior to Newer Volcanic period; b. " since " " "; c. doubtful

ANCIENT RIVER COURSES (pre-Newer Volcanic): a. still persisting; b. demonstrated; c. suggested

Fig. 35.—Plan showing the present and pre-newer basaltic streams of the central portion of the Werribee area, with other details concerning same.

basalt" series, there is no proof that this is the case; the amount of dissection and decomposition rather favour a greater age in many cases, but as already pointed out, such evidence is by no means conclusive.

West of Ballan, near Bradshaw's railway station, there was an old shallow east-flowing valley. This will no doubt be important when read in conjunction with what evidence the Moorabool gorges have to show, but alone it does not help our discussion.

At A, Fig. 35, we have a basalt tongue marking a buried valley, down which a deep and large stream flowed south. We may call it the Ancient Korweinguboora, since its territory is now drained by a creek of that name. This valley has also been proved by bores, just below the line of the Greendale fault. It had a south-easterly trend, but we do not know where it went beyond that part of its course shown in Fig. 35. The buried river valleys are in each case marked by a broken line of arrows in that figure.

At B, (Fig. 35), a small tributary of the Korjamumnip, the ancient Green Hills Creek, is also preserved under a newer basalt flow. These buried gravels were worked for gold, with much success.

At C (Fig. 35) we have the valley of the ancient Myrniong, filled by basalt, and already frequently referred to. There are no doubts as to the existence and direction of this old valley as far as the village of Myrniong. (See also Fig 21.) Beyond that our second method will be applied.

At D (Fig. 35) there is a small cap of basalt on Trig. Hill. It overlies waterworn gravels, and there appears to be a definite slope in its lower contact line. It is suggested that this basaltic cap marks the site of a small tributary valley that once flowed south-easterly through that point.

At E (Fig. 35) there is a long tongue of basalt reaching up to Bald Hill. It crosses the Werribee at a low level, and has already been referred to. It is underlain by waterworn gravels, and the writer believes it marks a south-flowing tributary. The present arrangement of the basalts of the locality suggests that, while the Trig Hill capping now stands about 400 feet higher, in pre-fault times the basalt may have simultaneously extended up the two valleys.

At F (Fig. 35) we have the ancient Bullengarook Creek, with its suggested southern continuation, while at G we have important evidence of a slightly different nature. At this point we are above the scarp, on that part of the plateau where the Melbourne-Ballarat railway runs. The basalt sheet may here be regarded as continuous, and yet we have evidence of a "tongue," the latter being exposed by the dissection at Dog Trap Gully. Along the right bank of this gully we see the basalt as a thin sheet covering the tertiary materials. On the left bank, basalt continues right to the bottom of the gully, and it is clear that Dog Trap Gully has cut its valley just alongside a large ancient basalt-filled valley. This old river flowed right across where the scarp now is, and it is difficult to know its exact course on the other side of the fault line.

The Parwan has cut right through the basalt sheet in the lowest part of its course, and the writer knows of no exposed basalt-filled sections there. There remains only the hard bar of basalt that the Parwan is still engaged in cutting through, just below the scarp, and in the reconstruction (Fig. 35), it is suggested that the ancient and important stream now being discussed turned southward there as shown by the arrows.

We have now, for comparison, two basalt-filled rivers crossing fault lines: (i.) the ancient Korweinguboora Creek, as already described, and (ii.) the case mentioned in the preceding paragraph. While in the former case the surface of the basaltic tongue maintains an even gentle grade right across the fault line, in the latter the surface of the basalt descends steeply for over 300 feet.

The second method of discovering ancient river beds is perhaps of greater interest, namely, to piece together the known sections of old valleys exposed in present river cuttings. The most complete evidence of this nature is to be found in the area of deep dissection in the neighbourhood of Werribee Gorge, and Fig. 36 represents that locality on a larger scale. Twelve separate old river sections are shown in this diagram, numbered 1 to 12.

The writer is greatly indebted to Mr. C. C. Brittlebank for a knowledge of the majority of these sections. That gentleman generously spent a part of his vacation in the field with the writer, conducting him to such places of interest as might be of value from the physiographic standpoint, and giving freely of his intimate knowledge of the whole Werribee area.

Nos. 1 and 2 (Fig. 36) are exposed in the valley of the Werribee about a mile above its junction with Pyke's Creek. The Werribee valley is here about 200 feet deep, but it has not yet cut quite through the basalt tongue. The old river valley section is well shown; it is cut in granodiorite, is probably about 150 feet deep, and with moderately sloping sides. A little higher up a small tributary valley came in from the west.

Nos. 3 and 4 (Fig. 36) are exposed in the Werribee not far from the western end of "The Island." The deep, present valley of the Werribee has here cut completely through the old valley, and the section exposed is similar in nature to Nos. 1 and 2, as are all the others as far as is known. Near section 3 a small tributary entered the ancient stream on the right bank.

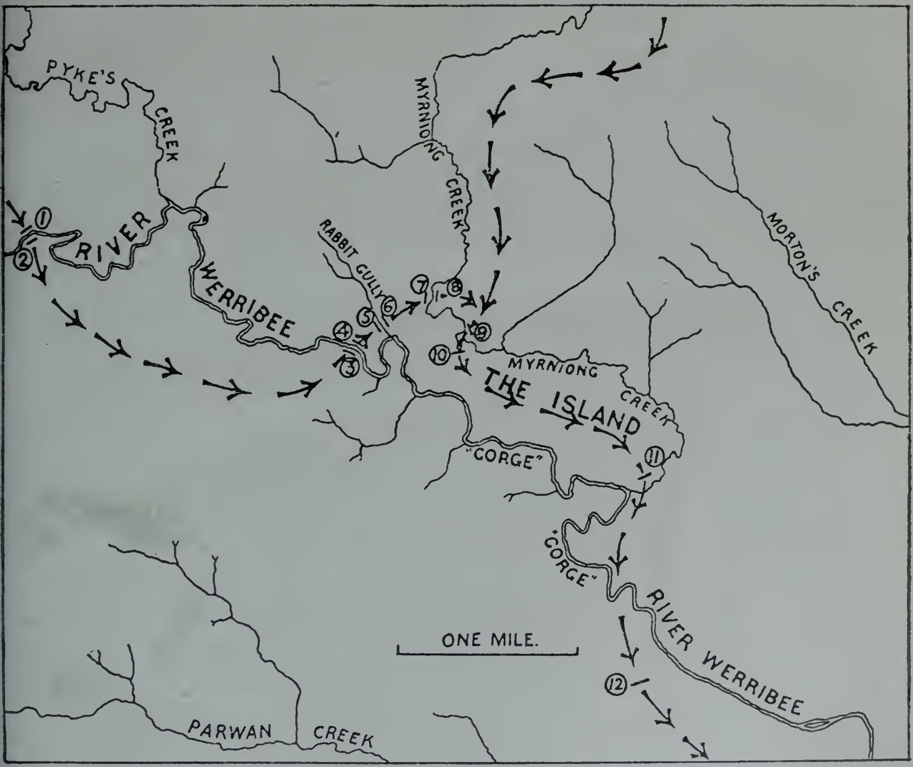


Fig. 36.—Plan to show locations of the various exposed sections of the "Pre-basaltic Werribee," as detailed in the context. With acknowledgments to C. C. Brittlebank.

Nos. 5 and 6 are exposed in a deep little valley called Rabbit Gully, and are likewise in granodiorite. Nos. 7 and 8, exposed in the valley of the present Myrniong, are not quite so clearly shown as the others described, but are nevertheless quite definite. The sections mentioned may be clearly linked up from an inspection of the surface distribution of the basalt, and the reconstruction is shown by arrows in Fig. 36. From its proximity to the present Werribee valley we may call this the "ancient Werribee."

Beyond sections 7 and 8 this stream junctioned with the "ancient Myrniong," and turned southerly to where sections 9 and 10 are exposed in the Myrniong, (Fig. 34). These have already been fully described; the Myrniong has not yet completely cut through this "tongue."

The ancient Werribee then turned eastward, and for the next mile its basalt filling has given rise to the well-known "Island" (see Fig. 20). Section No. 11 is shown at the eastern end of the Island, and a gap of one mile then occurs between sections 11 and 12. This gap is caused by the extensive erosion of the Werribee Gorge, but at least four small relics of basalt may be found along the line of the ancient valley here. A critical inspection of this rugged and difficult area from various viewpoints, and an examination of levels bring one to the conclusion that the course of the old river was approximately as shown by the arrows in Fig. 36. The old valley here was in Ordovician and glacial rocks. Section No. 12 is somewhat obscured by hill-slip material, but basalt occurs in situ at a low level, and from this point south-easterly the evidence of the sections may be linked up with that of the tongue exposed at Dog Trap Gully.

The whole of the available evidence from these sections is summed up in Fig. 36, and the course of the ancient Werribee is shown by a series of arrows, extending from section 1 and 2, right along to the scarp at Dog Trap Gully, a distance of eleven miles.

This knowledge has also been included in Fig. 35, and the rivers there marked by lines of arrows (both continuous and broken) show the pre-basaltic river system as far as the writer could determine it. While there are still many gaps, it is clearly shown that the river system was, south of the Greendale scarp, in an area of fairly low relief, with a general south-easterly trend.

(c) *The Plains and Swamps.*—Plains form no part of block A (the Blackwood and Lerderderg Ranges), nor of the eastern part of block C (the Brisbane Ranges), nor yet of block D (the Gisborne highlands).

Blocks B. and E. however, the Ballan and Port Phillip sunklands, are mainly plains. The only extensive level areas are those of a constructional type, built up either of—

(i.) Volcanic sheets.

(ii.) Alluvial material.

(i.) *Volcanic Sheets.*—The wide, open, grassy plains north and south from Ballan are of volcanic material. They were once much more extensive, and are being gradually destroyed by the rivers.

especially by the Parwan, the Werribee, and the Moorabool. Swamps are rare, only a few being known to the writer, one of them in a peculiarly interesting position. It has been mentioned that the divide between the Moorabool and the Werribee is mainly very low. Just west of Ballan, the Geelong water race from Korweinguboora traverses this divide in a trench a few feet deep.

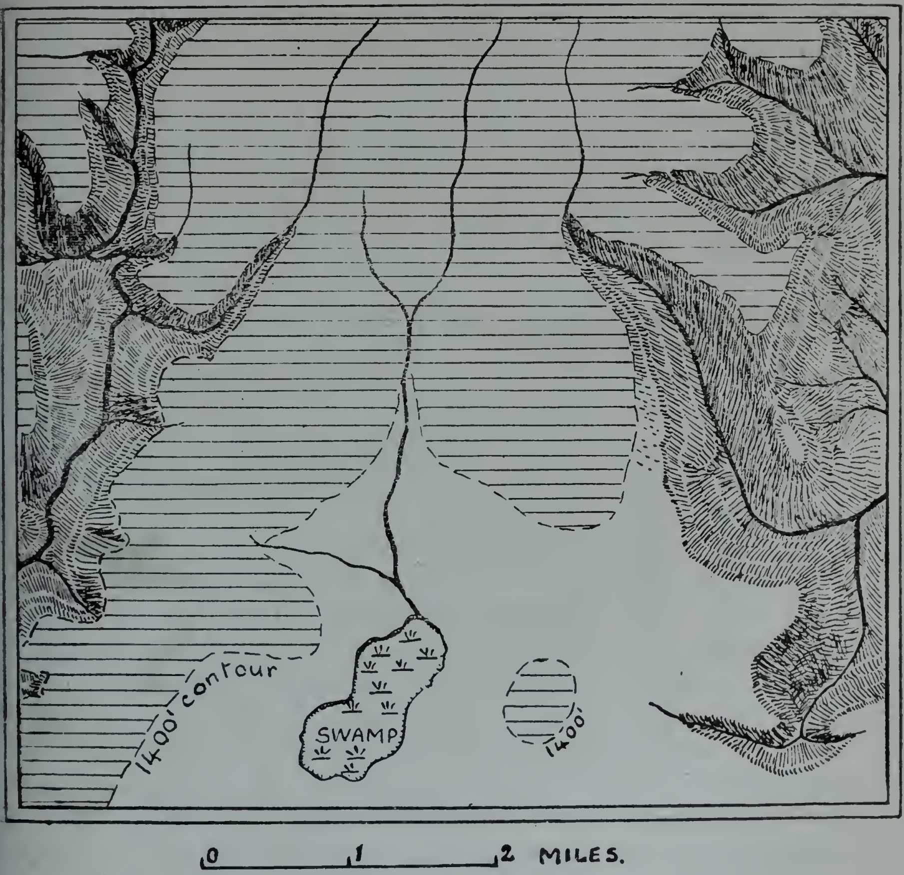


Fig. 37.—Plan of Swamp near Mount Wallace, showing nature of the divide between the Parwan Creek and the Eastern Moorabool. To illustrate some phases of the post-newer basaltic development of drainage, and also the nature of the divide between the Werribee and Moorabool basins in this locality. The Parwan is in the east of the plan, the Moorabool in the west.

Further south, below Mt. Hydewell, and immediately north of Mt. Wallace, the swamp occurs which is the subject of Fig. 37. To the west the Eastern Moorabool has entrenched itself in a gorge about 200 feet deep, while on the east the Parwan tributaries run steeply down to a depth of over 600 feet. The area between, less than three miles wide, is almost level, and both streams have small tributaries heading back to within a mile of each other. This level tract is a remnant of the once more extensive newer basalt sheet, and the part shaded horizontally stands above the 1400 feet contour line. A shallow south-flowing valley has chosen a central course, midway between the two competing streams and in the part left unshaded in the plan (between 1350 feet and 1400 feet) it forms a swamp in winter. (Fig. 37).

There is no doubt that we have here a case of (geologically) imminent capture. The southern bounding fault of the Ballan sunkland passes E.-W. through the central part of the swamp (beneath the basalt sheet). South of that line the bedrock is hard Ordovician, while to the north the basalt is underlain by the soft tertiaries. The capture should therefore take place to the north of the swamp, probably about the point where the two hachured tributaries most closely approach each other. The Parwan headwaters here have a much steeper grade than the Eastern Moorabool tributaries; both sets of streams are dry for the greater part of the year. Again, speaking geologically, we may look forward to the capture of the Eastern Moorabool by the Parwan even earlier than is suggested by Mr. Hart (ref. 22, p. 269).

The next great expanse of plain is that of the Lower Werribee ("Iramoo.") This aboriginal name was probably originally applied only to the more northern portions of the plains. These plains are wide and bleak, and are almost wholly volcanic, in places overlain by later alluvium. Here and there are small patches of timber, mainly box-trees, but these are most likely on places where an area of alluvium provides the necessary depth of soil. There is a general slope to the sea (see Fig. 12), and swamps are fairly common, especially close to the coast-line. The drainage is, of course, young, and is effected by the Werribee with the Skeleton Water Holes and Kororoit Creek to the north, and Little River, etc. to the south. A chain of swamps crosses the Bacchus Marsh-Geelong road, between Bald Hill and Parwan, and testifies to the backward stage of the drainage system in this portion of the plains.

The idea is put forward by Kitson (ref. 37) that the sea once extended over these plains, and that much of the lava was submarine. He bases this on the thickness and extent of pebbly drift, such as may be seen in exposures at Exford, etc. Examination by the writer showed nothing to suggest a marine origin for these gravels, and they are no doubt part of the material carried down from the western lifted blocks, and spread out over the plain before the Werribee had established its present valley. Even in the much deeper deposits at the town of Werribee, the only fossils found are those indicating fresh water.

(b) *Alluvial Plains.*—These are wholly confined to the Lower Werribee, excepting those on the western part of the upland block that forms the Brisbane Ranges. The latter, however, are more intimately connected with the physiography of the Moorabool basin. In the west of block E, these alluvial sheets spread out from the base of the Brisbane Ranges, and extend southward, embracing the You Yangs. It should some day be an irrigated area.

The triangular patch of deep alluvial, overlying basalt, which extends from the mouth of the Werribee up to the town of the same name, is an important agricultural district. This extensive irrigation settlement has suffered much in the past from the failure of the main storage reservoir, but it is confidently believed that this trouble is now over. Freshwater unio and fossil bones (Quarter Sheet 20 N.-E.) have been found in the alluvial of this area, which was doubtless formed under estuarine conditions at a comparatively recent date, when the general level of the land was somewhat lower than at present.

(iii.) *Bacchus Marsh Basin.*—The question of the origin of this important feature is one of some difficulty. Fig. 38 has been drawn to show the nature and extent of the basin. As we see from that sketch, there is about six and a-half square miles of flat country, with deep and rich alluvial soil; a more exact estimate gives about 4500 acres of irrigable land. The flats are formed where the most important tributaries of the Werribee all meet together. Thus we have in our sketch the Werribee, Korkuperrimul, Lerderderg, Goodman's, Parwan, and Pyrete all assisting in the building of these flats. The complex formations of the surrounding highlands, rich volcanics, sandstones, clays, etc., all send their tribute to be blended together for the building up of the wonderfully fertile soil of "the Marsh." The greater part of the work done in forming the Bacchus Marsh basin is apparently due to the Lerderderg. Close to the lowest "flats" are various slightly-elevated pebbly river terraces, and as we cross the bounding line between the two formations, we pass from land worth £80 an acre to land worth £2 10s. or less per acre. This is especially the case on the southern side of the basin, the higher ground on the western slopes having somewhat better values.

As already mentioned, Bacchus Marsh lies in a basin. To get out from this basin by road in any direction, it is necessary to ascend. The Werribee River makes its exit at the south-eastern

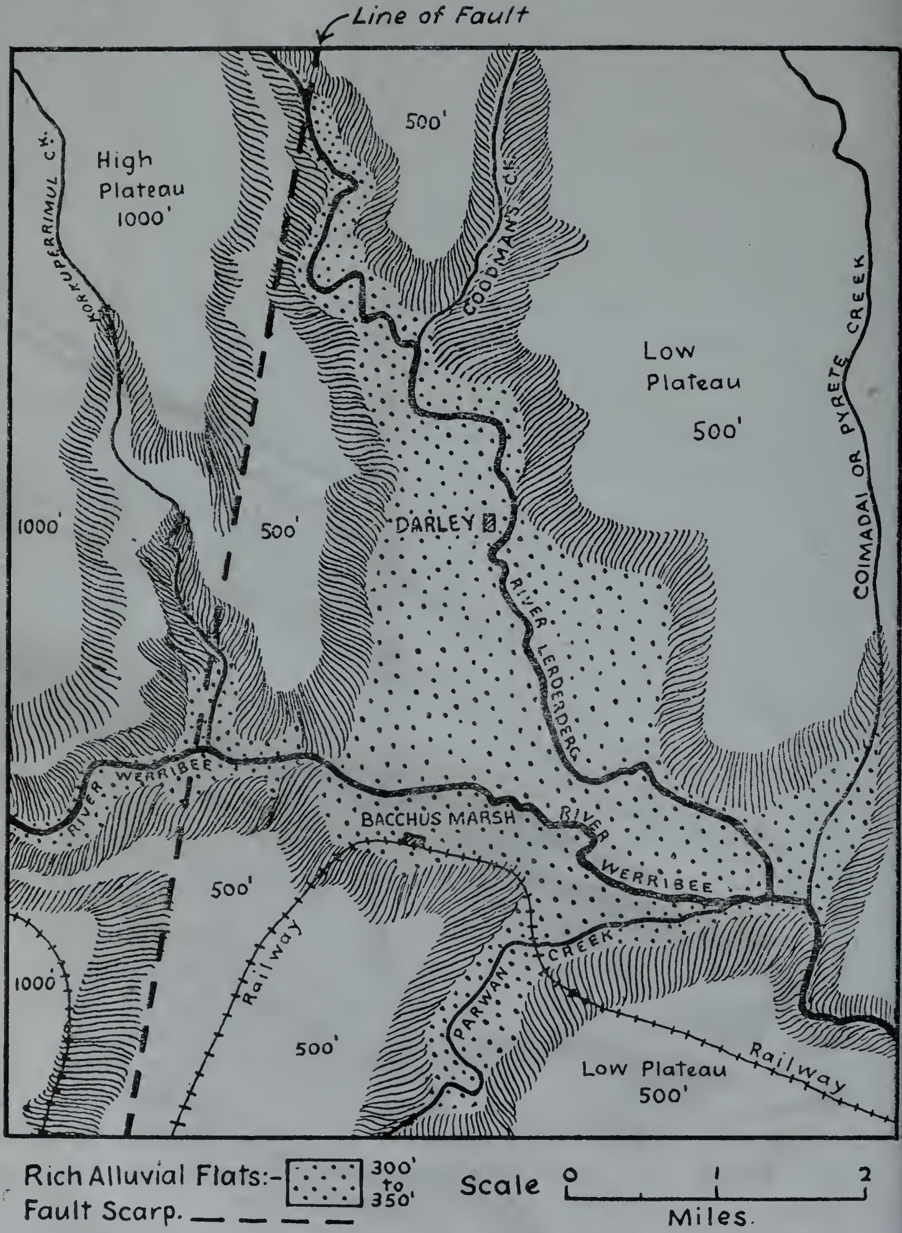


Fig. 38.—Plan to show the nature and extent of the Bacchus Marsh Basin, as described in detail in Section IXc.

end of the depression, through a gorge so narrow and deep that it cannot be availed of for any line of communication (see Fig. 38).

That this basin has been carved out by the rivers mentioned above is beyond dispute. It is easy to understand how, once the basin was commenced, the rivers would gradually extend it further outwards and down-stream, by "side swinging." The commencement of the basin was probably made by the Lerderderg and Werribee at their point of junction below the fault scarp. That junction must then have been at a point somewhere west of the town of Bacchus Marsh, and at a higher level than the present flats.

Hart (ref. 22), after discussing the erosion of the Parwan valley, says: "A similar explanation can be applied to Bacchus Marsh itself." It appears to the writer that there are important differences in origin between the Parwan Basin and the Bacchus Marsh basin, although the rocks worked in are closely similar. The Parwan Basin is on the up-throw side of the fault line, with the accompanying rejuvenation of its streams. The Bacchus Marsh basin lies on the down-throw side of the fault, where aggradational work would be done by the rivers, possibly until such time as the Lower Werribee established a channel in the newer basalt. The Parwan basin has been mainly accomplished by the *headward* erosion of steep tributary valleys. This can hardly have been the case with the Bacchus Marsh basin.

If the newer basalt covered the Bacchus Marsh area right up to the scarp, it is perhaps less easy to conceive how the start was made towards the formation of the basin and the flats. The preliminary factors that led to the origin of the Bacchus Marsh Basin may be stated thus:—

(1) The probable meeting near to and south of Bachus Marsh of at least two important pre-basaltic streams, the "ancient Werribee" and the "ancient Bullengarook."

(2) The filling of these valleys with newer basalts, which also spread out, covering much of the adjacent country, and overlying easily-eroded, level-bedded sands and clays.

(3) The meeting together of several important streams, on this area.

As the rivers, above the scarp, carved fairly deep gorges (see Fig. 30), they would also cut valleys through their own alluvial deposits at the base of the scarp, and, later, into the rocks below. Since the only course for these rivers was across the volcanic plains to the south-east, a channel was developed there in the basalts. As the lower part of the stream gradually deepened its valley in the hard basalt, the Lerderderg, Werribee, etc., in the neighbourhood of Bacchus Marsh would find time to widen their valley in the softer rocks, and then to meander in that valley, and so to form a "basin." The tendency would be to extend the basin down-stream by meanders, etc., undercutting the basalt sheet, which here overlies very soft sands and clays; thus the basin would be enlarged to embrace the junctions with the Parwan and Pyrete Creeks. Most of the work has been done subsequent to the rivers cutting through the basalt into the clays, etc., below. An examination of the limiting eastern wall of the basin, to the south and north of "Anthony's Hill," assists in confirming this view.

Remnants of the old apron of alluvium are still to be found in extensive coarse pebbly terraces that occur at different levels all along the western margin of the Bacchus Marsh flats. The soil of these terraces is much poorer and more difficult to irrigate than that of the "flats."

A smaller basin, quite similar in nature and origin to the Bacchus Marsh basin, occurs to the west of Bacchus Marsh, at "Blink Bonnie" farm. Here Lyell's Creek (the Korkuperrimul) and the Werribee meet behind a small lava tongue, which they have now quite cut through. The narrowing influence of this tongue of hard rock, with the flats formed in the softer rocks upstream, may be well seen in the field, and is suggested in Fig. 38.

Bacchus Marsh is so named after Captain W. H. Bacchus, who settled here with stock in 1838. Old maps show an area of marshy land near by, on the Lerderderg River, less than a mile from the place marked "Bacchus Station" (see Quarter Sheet 12 N.E.). No trace of this marsh now remains as the land is all drained and tilled—there is scarcely any doubt, however, that this marshy area gave the name to the locality.

X.—Economic Importance of the Physiographic Features.

The economic bearing of the various physiographic factors has been borne in mind throughout the paper, and frequently referred to. In this section the matter will be dealt with in the undermentioned order. Reference to the sections shown in Figs. 12 and 13, and the block diagram (Fig. 40), will be found helpful, while the large map (Plate XI.) has been specially drawn to illustrate this portion of the paper.

(a) Communications—Roads and Railways.
(b) Water Conservation.
(c) Population and Occupations.

(a) *Roads and Railways.*—The chief lines of communication in the Werribee area lie along the level plains of the Ballan and the Port Phillip Sunklands. The road and railway from Melbourne to Geelong both cross the lower Werribee plains, with that directness that characterises roads, etc., in an area of easy grades. Numerous other roads criss-cross the Werribee plains providing easy communication between Melbourne, Bacchus Marsh, Melton, Balliang, Little River, Werribee, Anakie, Geelong, etc. These roads are all in fairly good order, the main roads especially so.

The Ballarat-Melbourne railway and the main road between the same centres had of necessity to ascend the formidable obstacle of the Rowsley or Bacchus Marsh scarp, since that feature stands normal to the line joining these places, and extends for many miles to the north and south. The reality of this barrier is also suggested by the fact that the main or only communication between Ballarat and the seaboard was, for many years, through Geelong, along a route that avoided the scarp. This statement is based on the writer's recollections of the reminiscences of numerous pioneers of the "digging days," the early fifties; the chief mode of transport to Ballarat and the neighbouring diggings was, in those days, "by bullock dray from Geelong."

The grades above and below the Rowsley scarp present no difficulties, although the dissection of the upland "plains" has caused the present railway line to bend somewhat in places. The ascent of the scarp is made at Bacchus Marsh, where that feature is lowest. The train climbs the 1300 feet between Bacchus Marsh and Ingliston partly by means of a long loop, high grades prevailing all the way. The present road has been selected along the valley sides to the north of the Werribee, where the scarp is deeply dissected.

The roads from Melton to Gisborne, and from Bacchus Marsh to Bullengarook, both contain very steep pinches, where ascending from the plains to the uplifted block. Both roads are selected largely along basaltic flows, but neither is greatly used.

No road leads from the lower plains on to the Brisbane Ranges, excepting a very poor and little used road at the Anakies. The grades are high, and the scarp is possible of ascent here only because of the accumulation of the volcanic material of the Anakies close against it. An old railway survey also chose this route.

Communication within the Ballan sunkland is comparatively easy, and good roads are numerous. An exception occurs at the eastern end, where the agricultural area of Myrniong and Pentland Hills is cut off from the railway by the deep gorge of the Werribee. Their only outlet is via Bacchus Marsh, and this difficulty is a severe handicap to those concerned.

The uplifted block of the Blackwood and Lerderderg Ranges is almost roadless, although timber-getters and gold-miners had "tracks" in various directions. When Blackwood was a flourishing mining field, supplies were brought from Melbourne with difficulty; one track much used in those days took advantage of the gentler grade of the Mt. Blackwood lava flow, and then travelled along the ridge shown in Fig. 18, turning down into the valley of the Lerderderg at Blackwood. Another road climbs the scarp near Greendale, travelling up along the side of a small valley known as Long Gully, and then following the uneven ridge which separates the Back and Dale's Creeks. This is still the chief way of reaching Blackwood from the south, and is a very poor road. The best way to reach Blackwood is by a rather good road that winds down into the valley of the upper Lerderderg from the Main Divide, to the north. A short road runs northward across the Greendale Fault line to Blakeville, following mainly the newer-basalt tongue there. The difficulties of communication in this area are illustrated by the fact that one of the surveyed railway routes shown on the map (Plate XI.), from Ingliston to Bullarto, was estimated to cost £17,568 per mile, more than twice the average cost of the other projected routes shown. The townships on the Main Divide (Bullarto, Garlick's Lead, etc.), all have their chief or only communications to the northward. The main road that leads into the steeply-enclosed basin of the Parwan valley is of some interest; one would naturally expect it to follow the stream, but the narrow passage through the basalt at the edge of the Rowsley scarp makes that route quite impossible, and the road therefore climbs over the ridge somewhat to the south of that point. At least four other roads lead out of the Parwan valley, but they are practically impossible for ordinary traffic. The effect of the high ridge that now marks the long-reaching Bullengarook basalt flow is seen in the two old railway surveys that crossed that ridge west of Coimadai; long loops mark the location of the basalt-capped ridge. (Plate XI.) The importance of the abundance of basalt (for macadamizing) in most parts of the area has of course an important bearing on the nature of the roads. This fact is particularly noticeable when travelling in these localities more remote from the basalt supplies.

(b) *Water Conservation.*—This has already been fully dealt with in the opening sections. The main irrigation areas of Bacchus Marsh and Werribee are shaded in Plate XI., and the two chief storage reservoirs for those areas, at Pyke's Creek and Exford, are also indicated. Good catchment areas on the uplifted blocks still await the construction of storage dams, especially along the Lerderderg, whilst some large areas of level, low-lying alluvial country are yet without irrigation schemes. Rainfall, evaporation, etc., are fully discussed in Section V. (a). The recognition of the "dry belt" there referred to has an important bearing on land values on the lower Werribee plains.

(c) *Population and Occupations.*—The total population of the Werribee area is somewhat under 10,000. Of these the greater number are congregated about three centres which lie on the Werribee River itself—(See Plate XI.)—Werribee (about seven miles from the river mouth), Bacchus Marsh (in the centre of the area), and Ballan (about the centre of the Ballan sunkland).

Two once-important gold fields exist in the area, Blackwood in the centre of the Ordovician block A, and Steiglitz in the heart of the Ordovician block C. Both places are at present under eclipse. Other villages and townships occur, and all will be dealt with below, according to the geographical reasons for their locations, in the following order:—

(i). The lower Plains.
(ii.) Bacchus Marsh and Vicinity.
(iii.) The Ballan Sunkland.
(iv.) Blackwood and Lerderderg Ranges.
(v.) Brisbane Ranges.
(vi.) The Divides.

(i.) *The Lower Plains.*—The towns and villages of these wide basaltic plains are wholly centres of various agricultural activities, but enormous stretches of these plains are still used for grazing only. The rainfall is low, and irrigation is availed of to some extent; markets are handy, and transport easy. A number of villages in this list are not really in the Werribee basin, but are included since their localities have been dealt with in the paper:—

Werribee (Wyndham).—Twenty miles from Melbourne, on railway and main road. Farming and grazing. It is the second centre of importance in the Werribee basin. Two large establishments, the Metropolitan Farm and the Government Research Farm, are located here, and a large area is irrigated. The military authorities have taken advantage of these level plains for the establishment of the Central Flying School near by. Dr. Taylor has published interesting notes concerning these plains, from the point of view of the aviator, in the Commonwealth Meteorological Bureau reports.

Other small villages on the plains are:—Little River (Bulban), Melton, Laverton, Toolern Vale, Mount Cotterill, Anakie, Balliang, Rockbank, Truganina, Tarneit and Exford. Agriculture, with closer settlement, is taking the place of grazing in some areas. The future prosperity of these plains appears to lie in the extension of the irrigation system where possible.

(ii.) *Bacchus Marsh and Vicinity.*—The town of Bacchus Marsh is the chief centre of population in the Werribee basin. It owes its origin wholly to those geological forces that located and built the Bacchus Marsh basin. Irrigation has been wisely availed of, but has suffered much from the failure of the storage reservoirs in the past. The rich soils of the flats are used for dairying, fruit growing, lucerne growing, and general agriculture. The town is attractive, and is a favourite stopping place for travellers. The scenic beauties and scientific interest of the district attract many visitors. The village of Darley lies to the north, and in addition to the rich soils, the faulting has preserved large deposits of fire-clays, etc. (tertiary), and fair building stones (permo-carboniferous sandstones). Coimadai township is close by, and its valuable limestone deposits (tertiary) are also due to preservation by faulting, and later exposure by Pyrete Creek. Communication between Coimadai and Bacchus Marsh is greatly hampered by the occurrence between them of the high residual tongue of the Bullengarook basalt flow. A small antimony mine occurs in the Ordovician ranges to the north. Parwan and Rowsley are wholly agricultural and grazing, though good deposits of clays and building sands occur at Dog Trap Gully, near the latter place, and have been extensively worked.

(iii.) *The Ballan Sunkland.*—The varied rocks of this locality (see Fig. 13) provide good soils—newer and older volcanics, glacial sandstones, etc. The population is therefore chiefly farmers and graziers; the newer volcanic plains have but shallow soils in many cases, and are more used for grazing purposes. The town of Ballan itself has grown up chiefly as a centre for the various farming villages around it. Greendale, at the foot of the Greendale scarp, has well-grassed flats, and rounded hills of glacial sandstones and older basalts. Myrniong has similar soils, and both places are dairying and agricultural localities. Other townships are Ingliston, Mt. Wallace and Bunding—all on the volcanic plains, farming and grazing. There are quarries in the permo-carboniferous "freestones" of Greendale, which are occasionally worked.

(iv.) *Blackwood and Lerderderg Ranges.*—We find in these uplifted masses of bedrock a quite different population. The quartz reefs of the Ordovician and the timber of the ranges attract only miners and saw-millers. Blackwood is the chief township here, and was almost wholly mining—alluvial and quartz. Near by were the townships of Simpson's and Barry's reefs, both wholly mining. The village of Blakeville was largely a timber-getting centre, on account of its position in the ranges, and communication by an easy road to Ballan. Mining was also carried on. The tiny locality of Green Hills, well hidden in the ranges, is interesting. Here a small isolated lava flow covered up and preserved the river gravels of a short valley. This lava provided a limited area of good soils, the buried gravels were mined for gold, and the surrounding ranges were densely timbered; the locality thus became a mining, saw-milling and farming area. The two first-named industries have passed away, and a few farms alone remain.

The fairly dense forests that clothe the Ordovician ranges are for the most part at present closed to saw-millers for regeneration purposes. The great economic importance of these timber supplies must not be overlooked, especially in view of the growing appreciation of native hardwoods.

(v.) *Brisbane Ranges.*—As in the Blackwood ranges, gold-mining is the chief activity, Steiglitz being the main centre. In the western part, where newer basalts occur, there is some farming and grazing. To the south, where a let-down has preserved the younger rocks, tertiaries and older basalts, we get the fertile farming townships of Maude and Sutherland's Creek. The Geelong water supply has two reservoirs in these ranges at Durdiwarrah.

(vi.) *The Divide.*—On or near the Main Divide, where it bounds the Werribee basin on the north, there are three townships—Korweinguboora, Old Bullarto and Newbury (Garlick's Lead). All three are situated on areas of good volcanic soils, and are farming localities. In each case, also, the buried river gravels, below the lava flows, were worked for gold in the past.

XI.—Chronological Record of the Physiography of the Area.

This section is intended to act partly as a summary of the physiographic and geological events referred to in the preceding pages. Fig. 39 is drawn to recapitulate the physiographic history of this area in an "erosion column," analagous to the sedimentation column of geologists. Diastrophic periods of folding and faulting are suggested, and periods of vulcanicity and sedimentation are marked as breaks in the progress of erosion. Leaving out the Port Phillip sunkland, the underlying rocks of which are not exposed in this area, there is no evidence of any extensive marine transgression since the close of the lower Ordovician period. Traces of the "buried landscapes" of various periods are here and there available, and these have been marked in the column. Each geological system was given an approximately equal length of the column, which is therefore not to be regarded as a true "time line."

It will be seen from the column that, following the great lower Ordovician deposition, there has been no further marine sedimentation of any note in this area.

In consideration of the possibilities of various periods of sedimentation having affected marginal portions of the Werribee area. certain of these periods are indicated by small triangular insets on the left-hand side of the column (Fig. 39). Such periods may suggest, however vaguely, something of the general nature of the topography of this area during the long periods of erosion that followed the withdrawal of the sea at the close of the lower Ordovician period.

As already pointed out (Section VII (a)), the lower Ordovician sea or gulf covered the whole of the area here discussed, and extended well beyond its boundaries. Subsequent to the recession of this sea, a further marine transgression occurred in upper Ordovician times. Since richly fossiliferous rocks of this age occur on the Mornington Peninsula (east of Selwyn's fault), and probably below the Silurian at Diamond Creek (ref. 36), it is possible that the shores of this sea lay partly within the Werribee area. Similarly also the later marine encroachment of Silurian times is recorded in the rocks closely contiguous to this area, at and immediately westward of Melbourne.

There is evidence in the folding of the lower palaeozoic rocks that in middle to upper palaeozoic times great ranges of fold moun-

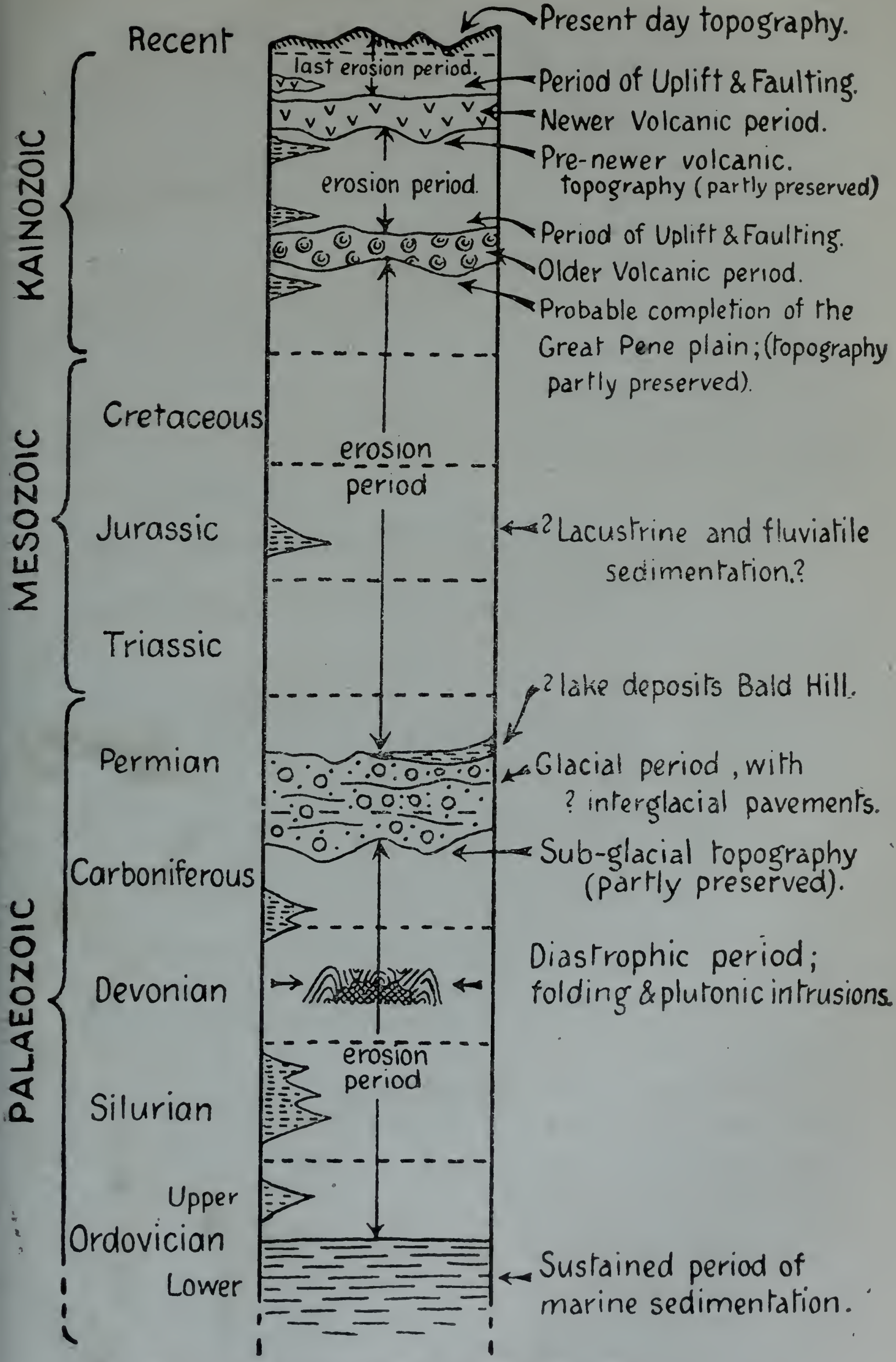


Fig. 29.—Chronological column, recording the order of the physiographic events affecting this area, referred to in detail in Section XI.